EFFECT OF PITCH PROGRAM VARIATIONS ON LAUNCH AVAILABILITY OF ATLAS/CENTAUR-AC-7 TO AC-15 (PHASE I)

Report Number GD/A-DDE64-045
28 December 1964

Contract Number NAS3-3232

Prepared By T. E. Johnson
T. E. Johnson
Dynamics Engineer

Technical Approval By R. E. Martin
R.E. Martin
Chief of Dynamics

Centaur Project Approval By R. S. Wentink
R. S. Wentink
Assistant Chief. Engineer
Design Analysis

GENERAL DYNAMICS/ASTRONAUTICS
A Division of General Dynamics Corporation
San Diego, California

The following persons and/or their engineering groups have been instrumental in preparing the information in this document. It is published with their concurrence; and any questions concerning it should be directed to them.

		Department	Extension
R.L. Holt	Design Specialist	Dynamics 512-1-2	4655
A.F. Leondis	Design Specialist	Dynamics 512-1-2	4674
C.D. Penegelley	Senior Dynamics Group Engineer	Dynamics 512-1	3295
J. Ingber	Senior Research Engineer	Aeroballistics 966-5	4205

Released for Publication by

C.B. Burkholder
Supervisor - Resources Control and Technical Reports, Centaur

Additional copies of this document may be obtained by contacting Department 954-4, Building 26, Plant 71, San Diego, California.

FOREWORD

This report, GD/A-DDE64-045, documents Phase I of a study to improve the Launch Availabilty of the Atlas/Centaur series AC-7 through AC-15. It documents the rules of analysis, presents data on launch capability, and indicates the course of action for further analysis, as well as presenting the benefits to be gained by improving pitch programs, increasing tank pressure, and reducing gust velocity criterion.

SUMMARY

Six initial pitch programs were generated by iterating the Atlas/Centaur trajectories to simultaneously meet payload, thermodynamic, aerodynamic, and inertia load constraints for launch during any season of the year. Each pitch program was selected to produce approximately zero angle-of-attack through one of six average wind profiles. Basic assumptions included a gust velocity criterion of 40 ft/sec., a factor of safety on bending moment and axial load of 1.25, 165,000 lb. thrust on each booster engine, Atlas LO_2 tank pressure of 28.5 psig after 20 seconds of flight and Centaur LH_2 tank pressure of 19.5 psia at liftoff. Using the above assumptions with six pitch programs and performing trajectory simulations on the IBM 7090 for real wind data, Tables 1-7 through 1-12 were obtained. From these tables, Figure 1-2 was constructed. It may be observed from Figure 1-2 that only three pitch programs are needed throughout the year. Use of the best three pitch programs produced a percent launch availability of 100 percent in July, 90 percent in August, 64 percent in June and September, 50 percent in May and October, 40 percent in January, November, and April, and 10 percent in February, March and December.

Since completion of this work, however, data has been obtained on the AC-5 configuration with a factor of safety on the axial load of 1.10, a gust velocity criterion of 30 ft/sec., an improved pitch program, and increased tank pressures based upon statistical telemetered data and quad tanking data. The minimum launch availability with this data has been tentatively increased to 50 percent and will be documented in the next report on this subject.

The work contained herein considers the benefit to the launch availability by increasing the Atlas LO_2 tank minimum pressure from 28.5 psig to 33.5 psig at 20 seconds of flight and by increasing the Centaur LH_2 tank minimum pressure from 19.5 psia to 22.0 psia at liftoff. This amount of pressure increase can increase the percent launch availability by as much as 20 percent, as shown in Figure 2-2. Also considered is a reduction in the gust velocity criterion from 40 ft/sec. to 30 ft/sec., which produces a launch availability increase of 23 percent in the worst winter months, as shown in Figure 2-4. Modifications of the initial pitch programs used in this study are expected to increase the launch availability because the biassing is based on real wind profiles instead of average profiles. Not considered in this report is the use of an axial load factor of safety of 1.10 instead of 1.25. The reduced factor of safety increases the launch availability by 8 to 10 percent.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Continued)

EFFECTS OF PITCH PROGRAM VARIATIONS ON LAUNCH AVAILABILITY OF ATLAS/CENTAUR AC-7 TO AC-15 (PHASE I)

SECTION I

INTRODUCTION

1.1 OBJECTIVE

The purpose of this document is to investigate possible methods to improve launch capability of the Atlas/Centaur vehicle beginning with the AC-7 configuration, as defined in Reference 1, and continuing on through to the AC-15 configuration.

Accomplishment of this task can be achieved by improving the current three best pitch programs, increasing pressure in the Atlas and Centaur tanks, and reducing the gust velocity criterion.[1]

Note[1]

For this study (1-cosine) gust with a maximum gust velocity of 40 ft/sec is being used. Since the wind profiles are derived from balloon data which is taken every 1000 ft. the gust velocity criteria is to approximate the short wave length phenomena and include the effects of transonic buffet, errors in balloon and radar measurements, and the lack of persistence of the wind profile between the time of observation and the time of flight. This report shows the effect of reducing the gust velocity criterion, and not the justification which is subject to consideration.

This section offers data on wind profiles, pitch programs, and existing percent launch availability information. Later sections detail, along with graphs, mathematical equations, and tables, the suggested methods for improving launch capability, pitch programs, and yaw programs.

1.2 WIND PROFILES AND PITCH PROGRAMS

The starting point for this study was to select from the set of AMR mean monthly wind profiles, documented in Reference 2, a reduced set which would be representative of the mean variation throughout the year. The intent was to generate a series of pitch programs which would cover the entire year with a nearly optimum launch availability.

It was observed that certain months of the year had mean wind profiles similiar to other months. These were consequently grouped and approximated by a single wind function. A total of six wind profiles (WP) were constructed and labeled (130, 100, 70, 30, 0, -20) corresponding to the value of the wind velocity of each profile at an altitude of 40,000 feet. The AMR mean monthly profiles and the constructed set of six functions are shown in Figure 1-1. These are representative of the spectrum of monthly variations.

1.2.1 PITCH PROGRAM. Corresponding to each of the six Wind Profiles (WP), a set of six Pitch Programs (PP) were developed which maintained the vehicle at approximately zero angle-of-attack through the region of maximum dynamic pressure and then to booster engine cutoff (BECO). The pitch programs are stepped functions which conform to the input requirements of the Atlas autopilot.

The pitch programs and months they pertain to are as follows:

a. February March December	PP130
b. January November April	PP100
c. May October	PP70
d. September June	PP30
e. August	PP0
f. July	PP(-20)

Pitch programs are defined by their pitch rates or the rate at which the vehicle is pitching over as the altitude increases. The pitch rates are summarized in Tables 1-1 to 1-6 for the six pitch programs mentioned previously.

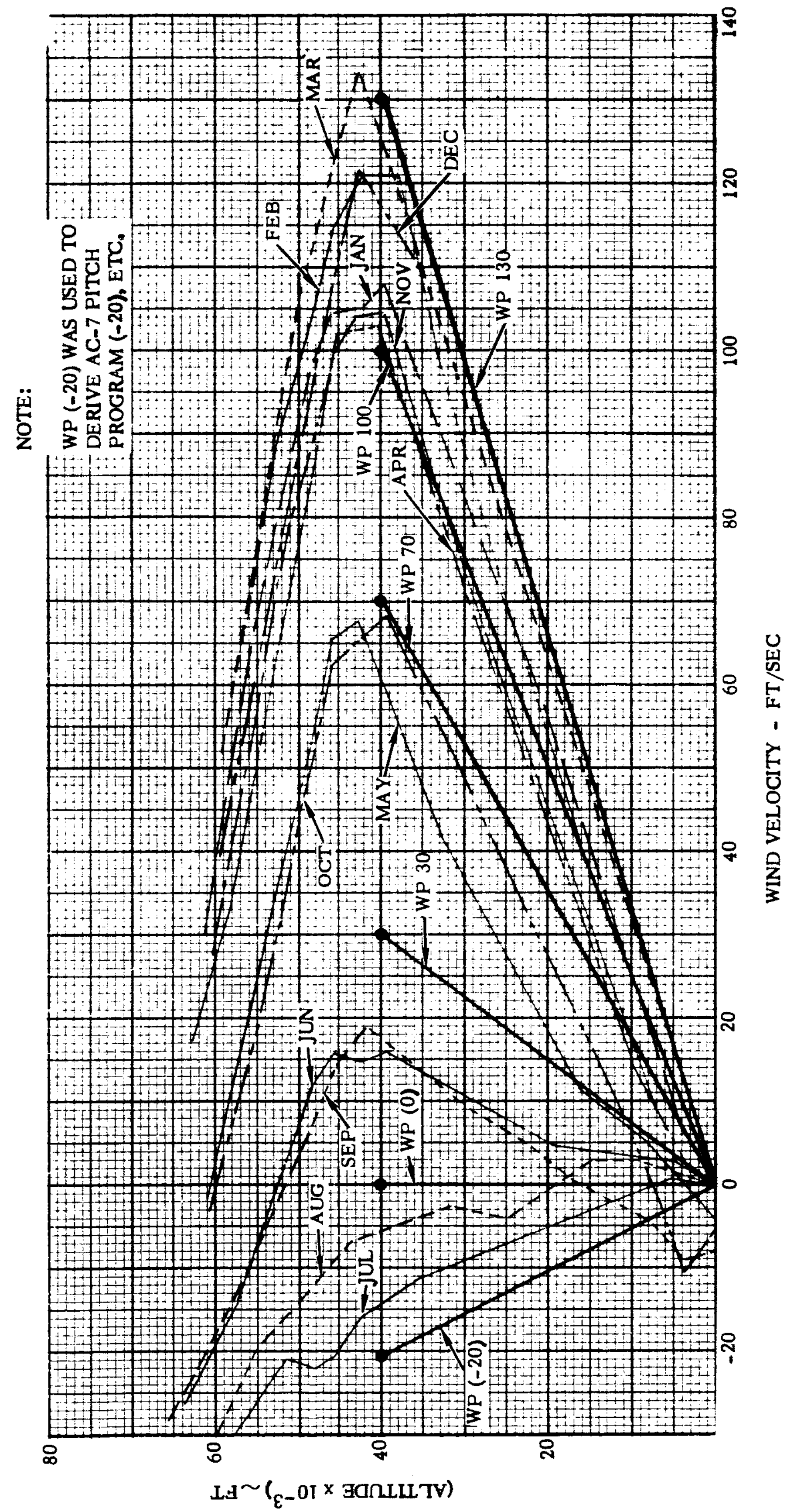


Figure 1-1. AMR Monthly Mean Wind Profiles

2W01ST

TABLE 1-1. PITCH RATES FOR PITCH PROGRAM (130)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-64	.6375
64-72	.5865
72-82	.7650
82-90	.6650
90-96	.5865
96-102	.4335
102-114	.3570
114-128	.3060
128-160	.2295

TABLE 1-2. PITCH RATES FOR PITCH PROGRAM (100)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-46	.6120
46-62	.6885
62-74	.6375
74-80	.7905
80-90	.6630
90-98	.5610
98-112	.3825
112-128	.3060
128-160	.2295

TABLE 1-3. PITCH RATES FOR PITCH PROGRAM (70)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-42	.575
42-58	.700
58-74	.650
74-82	.750
82-90	.650
90-98	.550
98-112	.400
112-122	.325
122-160	.250

TABLE 1-4. PITCH RATES FOR PITCH PROGRAM (30)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-38	.5271
38-48	.7028
48-58	.7530
58-84	.7028
84-94	.6024
94-108	.4518
108-126	.3263
126-160	.2259

TABLE 1-5. PITCH RATES FOR PITCH PROGRAM (0)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-34	.4769
34-44	.6777
44-64	.7530
64-80	.7028
80-88	.6526
88-96	.5522
96-104	.4769
104-118	.3765
118-160	.2510

TABLE 1-6. PITCH RATES FOR PITCH PROGRAM (-20)

Time In Flight (seconds)	Pitch Rate (degrees/second)
0-15	.00
15-32	.4369
32-46	.6939
46-64	.7710
64-82	.7196
82-92	.5911
92-104	.4883
104-116	.3855
116-126	.3084
126-150	.2313

Thirty winds were run for the month in which the pitch program was designed, and in the months for which the pitch program was not designed, it was assumed that 10 runs would be sufficient. This makes a total of 80 runs per pitch program.

1.3 PRESENT PERCENT LAUNCH AVAILABILITY

To find the present percent launch availability, Stations 219, 410, 568, and 770 were checked by use of the SC 4020 plots of the IBM 7090 trajectory solutions to determine if the design limit bending moments were exceeded and the engine deflection in the pitch plane was also checked, utilizing data from Reference 3, to determine if it had exceeded its allowable value. The results are shown in Table 1-7 through Table 1-12.

1.3.1 MONTHLY PITCH PROGRAM EVALUATION. To calculate the percent launch availability, the number of runs in which the values of bending moment and engine deflection had not exceeded the allowable design limit was divided by the total number of runs, and then multiplied by one hundred. Figure 1-2 plots the percent launch availability versus months for all the pitch programs.

TABLE 1-7. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 130 AND Vg = 40 FT/SEC

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
JAN	1955 10		X		X	
NOV	15	X	X		X	
APR	1956 12	X	X	X	X	X
	15					
L.A.=40%	1957 12					
	19					
	1958 12	X	X	X	X	X
	15	X	X	X	X	X
	1959 12					
	15	X	X	X	X	X
MAY	1958 11					
OCT	16					
	1959 11		X			
L.A.=40%	16		X			
	1960 11	X	X	X	X	
	16					
	1961 11	X	X	X	X	X
	16		X			
	1962 11		X		X	
	16					
JULY	1958 11		X		X	X
	16		X		X	X
L.A.=0%	1959 11		X		X	X
	16	X	X	X	X	X
	1960 11		X		X	X
	16	X	X	X	X	
	1961 11		X		X	X
	16		X	X	X	X
	1962 11	X	X	X	X	X
	16	X	X	X	X	X
AUG	1958 11					
	16		X		X	X
L.A.=20%	1959 11		X			X
	16					X
	1960 11	X	X	X	X	X
	16		X		X	X
	1961 11	X	X	X	X	X
	16					
	1962 11	X	X	X	X	
	16		X	X	X	X
SEPT	1958 11				X	X
JUNE	16		X			X
	1959 6		X		X	X
L.A.=10%	11					
	1960 11	X	X		X	X
	16		X		X	X
	1961 11	X	X	X	X	
	16		X		X	X
	1962 11	X	X	X	X	X
	16	X	X	X	X	X
FEB	1955 2					
MAR	5	X	X	X	X	X
DEC	11	X	X	X	X	
	17	X	X	X	X	X
L.A.=10%	23		X		X	
	26		X		X	
	1956 2				X	
	5	X	X	X	X	
	11	X	X	X	X	X
	14		X		X	
	17					
	23				X	
	1957 2		X			
	5					
	11		X		X	X
	17	X	X	X	X	X
	20	X	X	X	X	
	26	X	X	X	X	X
	1958 1	X	X	X	X	X
	5		X		X	X
	11	X	X	X	X	X
	17	X	X	X	X	X
	20	X	X	X	X	
	26	X	X	X	X	
	1959 2	X	X	X	X	
	5	X	X	X	X	X
	11	X	X	X	X	
	17		X	X	X	
	20	X	X	X	X	X
	25	X	X	X	X	X

X: Exceeds Allowable

TABLE 1-8. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 100 AND Vg = 40 FT/SEC

	Date	Bending Moment At Station				Eng. Def.
		219	410	568	770	δp
FEB	1955 11	X	X	X	X	
MAR	17	X	X	X	X	X
DEC	1956 11	X	X	X	X	X
	17				X	
L.A. = 0%	1957 11		X	X	X	
	17	X	X	X	X	
	1958 11	X	X	X	X	
	17	X	X	X	X	X
	1959 11	X	X	X	X	
	17	X	X	X	X	X
MAY	1958 11					
OCT	16					
	1959 11					
L.A. = 50%	16				X	
	1960 11	X	X	X	X	
	16					
	1961 11	X	X	X	X	X
	16					
	1962 11		X		X	
	16		X			
JULY	1958 11					
	16					
L.A. = 40%	1959 11					X
	16		X		X	X
	1960 11					
	16		X		X	X
	1961 11					
	16		X			X
	1962 11		X		X	X
	16		X	X	X	X
AUG	1958 11					
	16		X			
L.A. = 80%	1959 11					
	16					
	1960 11		X		X	X
	16					
	1961 11					
	16					
	1962 11					
	16					

	Date	Bending Moment At Station				Eng. Def.
		219	410	568	770	δp
SEPT	1958 11					
JUNE	16					
	1959 11					
L.A. = 50%	21					
	1960 11	X	X		X	X
	16					
	1961 11	X	X	X	X	
	16					X
	1962 11		X		X	X
	16	X	X	X	X	X
JAN	1955 3					
NOV	6		X			X
APR	10		X		X	
	15		X			
L.A. = 20%	21	X	X	X	X	X
	27	X	X	X	X	X
	1956 3		X		X	
	6					
	12	X	X	X	X	
	15					
	21	X	X	X	X	X
	27		X		X	
	1957 3		X		X	X
	6	X	X	X	X	X
	12					
	19				X	
	21		X		X	
	27					
	1958 3	X	X	X	X	X
	6	X	X	X	X	X
	12	X	X	X	X	X
	15	X	X	X	X	X
	21	X	X	X	X	X
	27	X	X	X	X	X
	1959 3		X		X	
	6	X	X	X	X	
	12					
	15	X	X	X	X	X
	21		X			
	27		X		X	

X: Exceeds Allowable

TABLE 1-9. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 70 AND Vg = 40 FT/SEC

	Date	Bending Moment At Station				Eng. Def.
		219	410	568	770	δp
JAN	1955 10		X		X	
NOV	15		X		X	
APR	1956 12	X	X	X	X	X
	15					
L.A.=30%	1957 12					
	19		X		X	
	1958 12	X	X	X	X	X
	15	X	X	X	X	X
	1959 12					
	15	X	X	X	X	X
FEB	1955 11	X	X	X	X	
MAR	17	X	X	X	X	X
DEC	1956 11					
	17		X			
L.A.= 0%	1957 11		X	X	X	X
	17	X	X	X	X	X
	1958 11	X	X	X	X	
	17	X	X	X	X	X
	1959 11	X	X	X	X	
	17	X	X	X	X	X
JULY	1958 11					
	16					
L.A.= 50%	1959 11					
	16		X		X	X
	1960 11					
	16		X			X
	1961 11					
	16					X
	1962 11				X	X
	16		X		X	X
SEPT	1958 11					
JUNE	16					
	1959 11					
L.A.= 60%	16					
	1960 11	X		X	X	X
	16					
	1961 11	X	X	X	X	
	16					
	1962 11		X		X	X
	16		X		X	X

	Date	Bending Moment At Station				Eng. Def.
		219	410	568	770	δp
AUG	1958 11					
	16					
L.A.= 90%	1959 11					
	16					
	1960 11		X		X	X
	16					
	1961 11					
	16					
	1962 11					
	16					
MAY	1958 1				X	
OCT	6					
	11					
L.A. =43.3%	16					
	21		X	X	X	
	26	X	X	X	X	
	1959 1					
	6	X	X	X	X	X
	11					
	16		X		X	
	21		X		X	X
	26		X			
	1960 1					
	6		X	X	X	X
	11	X	X	X	X	X
	16					
	21					
	26	X	X	X	X	X
	1961 1		X		X	
	6				X	
	11	X	X	X	X	X
	16					
	21					
	26	X	X	X	X	X
	1962 1					
	6		X	X	X	X
	11		X		X	
	16		X		X	
	21					
	26					

X: Exceeds Allowable

TABLE 1-10. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 30 AND Vg = 40 FT/SEC

	Date		Bending Moment At Station				Eng. Def.
			219	410	568	770	δ_p
JAN	1955	10	X	X	X	X	
NOV		15		X		X	
APR	1956	12	X	X	X	X	X
		15					
L.A. =20%	1957	12		X		X	
		19		X		X	
	1958	12	X	X	X	X	X
		15	X	X	X	X	X
	1959	12					
		15	X	X	X	X	X
FEB	1955	11	X	X	X	X	
MAR		17	X	X	X	X	
DEC	1956	14		X	X	X	
		17		X		X	
L.A.= 0%	1957	14	X	X	X	X	
		17	X	X	X	X	X
	1958	11	X	X	X	X	X
		17	X	X	X	X	X
	1959	14		X		X	
		17	X	X	X	X	X
MAY	1958	11					
OCT		16					
	1959	11					
L.A. =30%		16		X		X	X
	1960	11	X	X	X	X	X
		16				X	
	1961	11	X	X	X	X	
		16				X	
	1962	11	X	X	X	X	
		16		X	X	X	
JULY	1958	11					
		16					
L.A.= 100%	1959	11					
		16					
	1960	11					
		16					
	1961	11					
		16					
	1962	11					
		16					

	Date		Bending Moment At Station				Eng. Def.
			219	410	568	770	δ_p
AUG	1958	11					
		16					
L.A.=90%	1959	11					
		16					
	1960	11		X			
		16					
	1961	11					
		16					
	1962	11					
		16					
SEPT	1958	1					
JUNE		6		X		X	
		11					
L.A.=63%		16					
		21				X	
		26					
	1959	1					
		6					
		11					
		16		X			
		21		X		X	
		26					
	1960	1					
		6					
		11		X		X	
		16					
		21	X	X	X	X	X
		26					
	1961	1					
		6		X	X	X	X
		11	X	X	X	X	X
		16					
		21					
		26					
	1962	1					
		6					
		11					X
		16				X	
		21		X		X	
		26					

X: Exceeds Allowable

TABLE 1-11. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 0 AND Vg = 40 FT/SEC

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
JAN	1955 10	X	X	X	X	X
NOV	15		X	X	X	X
APR	1956 12	X	X	X	X	X
	15		X		X	
L.A. = 10%	1957 12	X	X	X	X	X
	19		X	X	X	X
	1958 12	X	X	X	X	X
	15	X	X	X	X	X
	1959 12					
	15	X	X	X	X	X
FEB	1955 11	X	X	X	X	
MAR	17	X	X	X	X	
DEC	1956 14		X	X	X	
	17		X	X	X	
L.A. = 0%	1957 14	X	X	X	X	
	17	X	X	X	X	X
	1958 11	X	X	X	X	X
	17	X	X	X	X	X
	1959 14	X	X	X	X	
	17	X	X	X	X	X
MAY	1958 11					
OCT	16					
	1959 11					
L.A. = 30%	16		X		X	X
	1960 11	X	X	X	X	X
	16				X	
	1961 11	X	X	X	X	
	16		X		X	
	1962 11	X	X	X	X	X
	16		X	X	X	X
JULY	1958 11					
	16					
L.A. = 100%	1959 11					
	16					
	1960 11					
	16					
	1961 11					
	16					
	1962 11					
	16					

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
AUG	1958 1					
	6					
L.A. = 86%	11					
	16					
	21					
	26					
	1959 1		X		X	X
	6		X		X	X
	11					
	16					
	21					
	26					
	1960 1					
	6					
	11					
	16					
	21					
	26					
	1961 1					
	6					
	11					
	16					
	21					
	26				X	
	1962 1					
	6					
	11		X			
	16					
	21					
	26					
SEPT	1958 11					
JUNE	16					
	1959 11					
L.A. = 60%	21		X	X	X	X
	1960 11		X		X	
	16					
	1961 11	X	X	X	X	X
	16					
	1962 11					
	16				X	

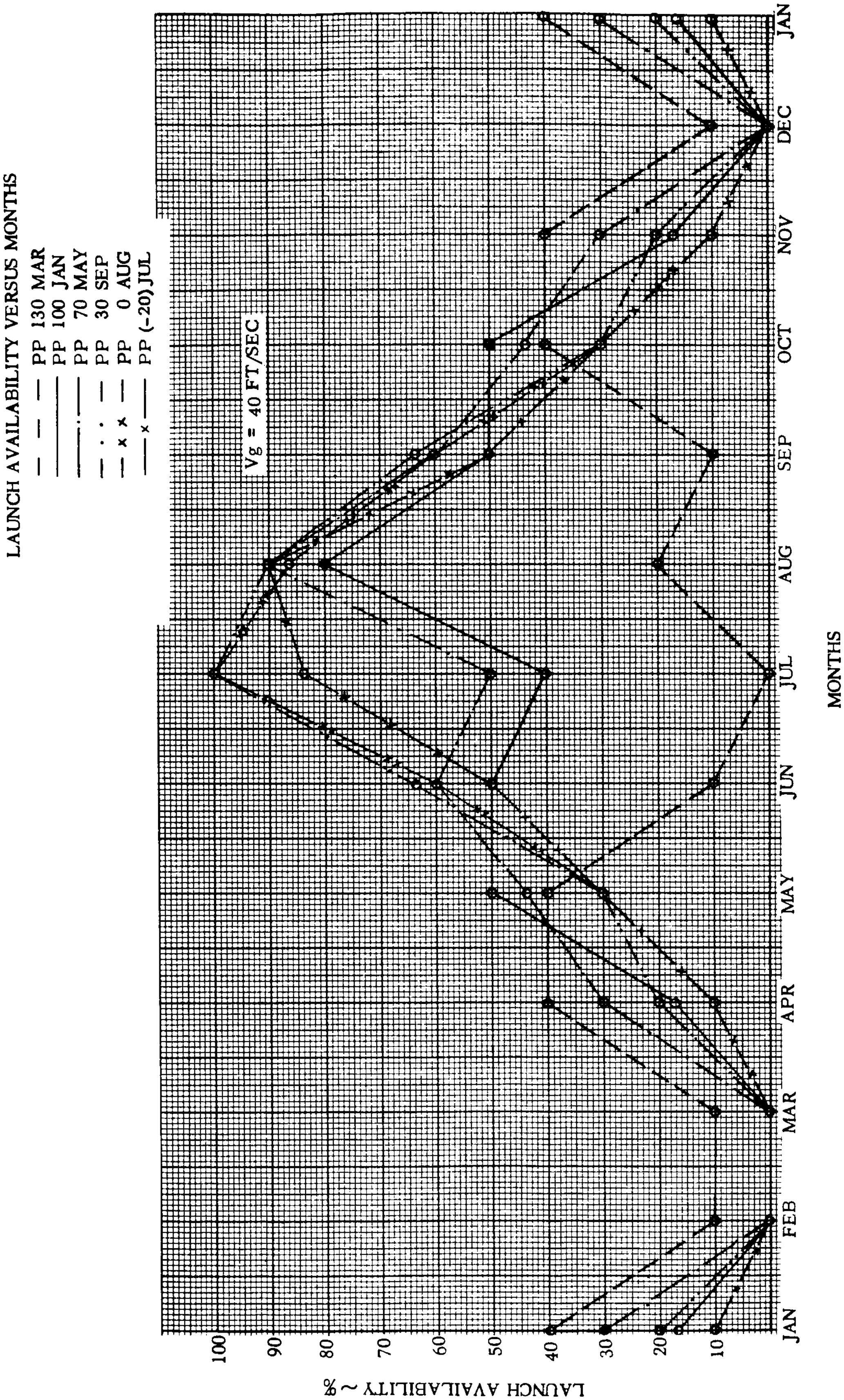
X: Exceeds Allowable

TABLE 1-12. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM (-20) AND Vg = 40 FT/SEC

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
JAN	1955 10	X	X	X	X	X
NOV	15	X	X	X	X	X
APR	1956 12	X	X	X	X	X
	15		X		X	
L.A.= 10%	1957 12	X	X	X	X	X
	19		X	X	X	X
	1958 12	X	X	X	X	X
	15	X	X	X	X	X
	1959 12					
	15	X	X	X	X	X
FEB	1955 11	X	X	X	X	X
MAR	17	X	X	X	X	
DEC	1956 11	X	X	X	X	
	17		X	X	X	X
L.A.= 0%	1957 11	X	X	X	X	X
	17	X	X	X	X	X
	1958 11	X	X	X	X	X
	17	X	X	X	X	X
	1959 11	X	X	X	X	
	17	X	X	X	X	X
MAY	1958 11					
OCT	16					
	1959 11					
L.A.= 30%	16		X		X	X
	1960 11	X	X	X	X	X
	16		X		X	
	1961 11	X	X		X	
	16		X	X	X	
	1962 11	X	X	X	X	X
	16		X	X	X	X
AUG	1958 11					
	16					
L.A. = 90%	1959 11					
	16					
	1960 11					
	16					
	1961 11					
	16					
	1962 11		X			
	16					

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
SEPT	1958 11					
JUNE	16					
	1959 11				X	
L.A.= 50%	16		X	X	X	
	1960 11		X		X	
	16					
	1961 11	X	X	X	X	
	16					
	1962 11					
	16				X	
JULY	1958 1					
	6					
L.A.= 83%	11					
	16					
	21		X		X	X
	26					
	1959 1					
	6					
	11					
	16				X	
	21				X	
	26	X	X		X	
	1960 1		X		X	
	6					
	11					
	16					
	21					
	26					
	1961 1					
	6					
	11					
	16					
	21					
	26					
	1962 1					
	6					
	11					
	16					
	21					
	26					

X: Exceeds Allowable



2W02ST

Figure 1-2. Comparison of Six Pitch Programs for Each Month of the Year

SECTION II

IMPROVED PERFORMANCE ON LAUNCH AVAILABILITY

2.1 GENERAL

This section presents, with graphs, tables, and equations, methods which will improve the launch capability of the Atlas/Centaur vehicle.

2.1.1 BEST PITCH PROGRAMS. By taking note of Figure 1-2, it can be observed that the best pitch programs are as follows:

a.	November December January February March April	PP 130
b.	May October	PP 100
c.	June July August September	PP 30

Using the three best pitch programs, Figure 2-1 was then obtained. This plot indicates the present best percent launch availability for the complete year.

2.1.2 INCREASE IN TANK PRESSURE. The following derivation will show how an increase in tank pressure will allow an increase in bending moment. The axial tensile stress in a tank is given as $\sigma_a = \frac{pr}{2t}$ and the bending stress is given as $\sigma_b = \frac{M}{\pi r^2 t}$. Now let $\sigma_a = \sigma_b$ then $p = \frac{2M}{r^3 \pi}$.

If p = 1 psi and r = 60" then $M = .340 \times 10^6$ in.-lb. This means that an increase in pressure of 1 psi will allow an increase in ultimate bending moment equal to $.340 \times 10^6$ in.-lb. Application of the factor of safety of 1.25 will produce a limit bending moment of $.272 \times 10^6$ in.-lb. per 1 psi increase in tank pressure. It may be noted from one of the SC 4020 Bending Moment plots that if Δp = 1 psi in the Atlas tank then only Δp = 1/2 psi is needed in the Centaur tank. Pitch Program 30 for the months of September and June will be used as an example and the results of increasing tank pressure is illustrated in Figure 2-2.

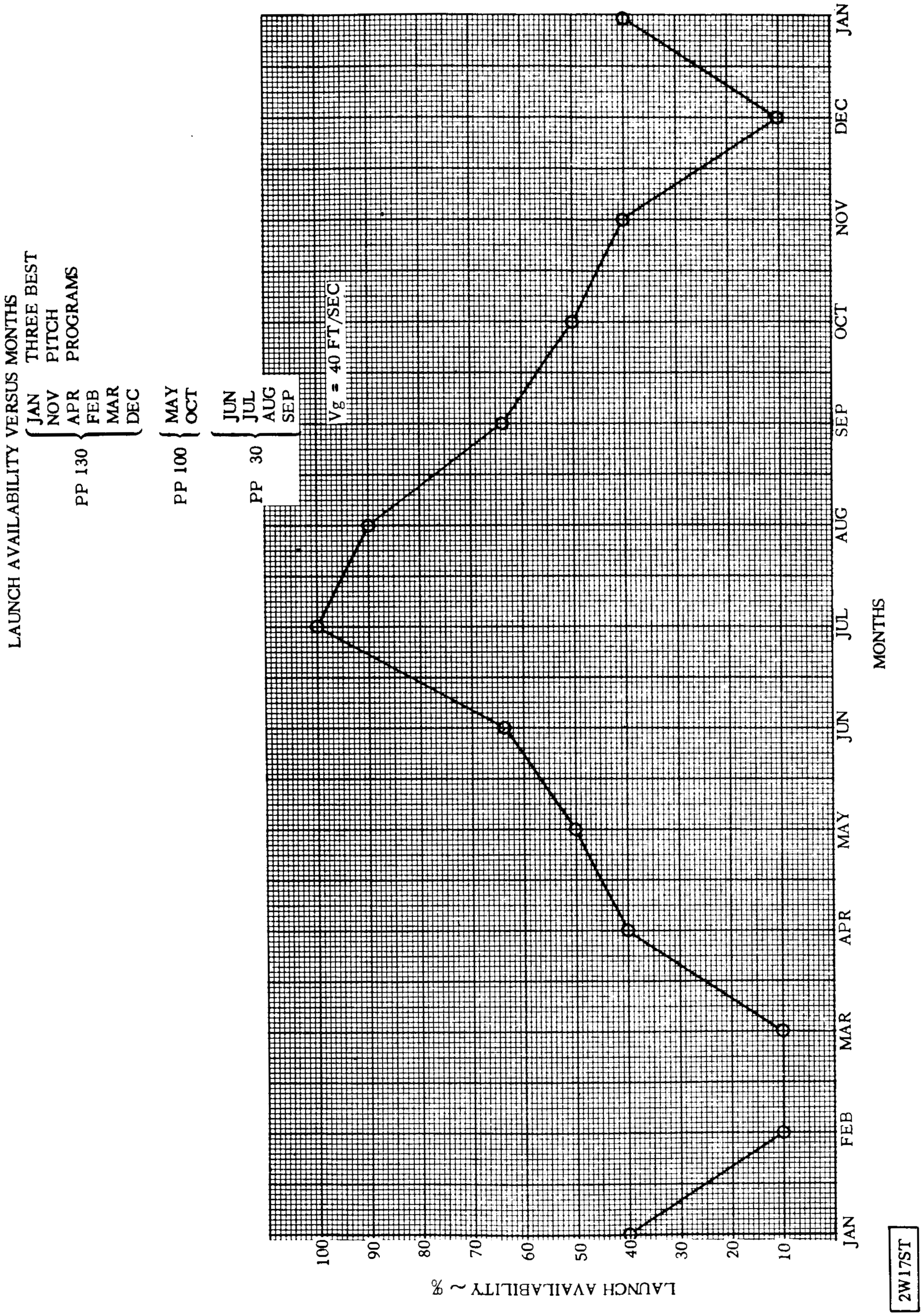
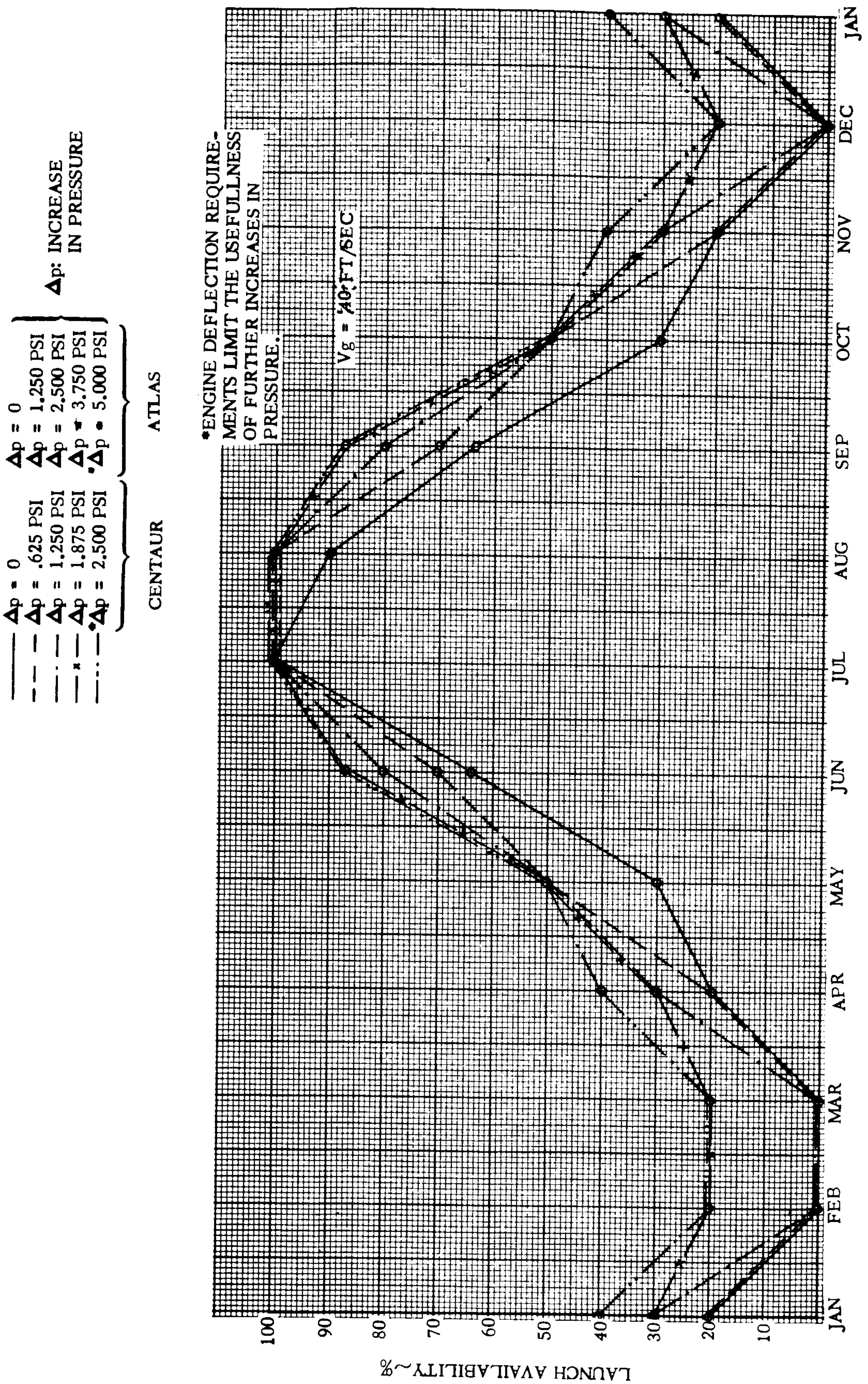


Figure 2-1. Envelope of the Best Pitch Programs During Each Month

The solid line in Figure 2-2 represents the present percent launch availability. The broken lines indicate increase in percent launch availability due to an increase in pressure in the Atlas and Centaur tanks.

2.1.3 REDUCTION IN THE GUST VELOCITY CRITERION. The gust velocity criterion for this study is 40 ft/sec. It was decided to reduce the gust velocity criterion to 30 ft/sec. and see how much the percent launch availability would be increased. The three best pitch programs were checked resulting in Tables 2-1 through 2-3. For additional information on reduction in gust velocity criterion see Note[1] on page 1-1.

Figure 2-3 plots the new launch availability curves for PP 130, PP 100, and PP 30. It may now be observed that only PP 130 and PP 30 are needed if Vg = 30 ft/sec. is used. Figure 2-4 shows the comparison between Vg = 40 ft/sec. and Vg = 30 ft/sec.



2W18ST

Figure 2-2. Effects of Tank Pressure on Launch Availability Versus Months for PP 30

TABLE 2-1. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 130 AND Vg = 30 FT/SEC

		Bending Moment At Station				Eng. Def.			Bending Moment At Station				Eng. Def.
	Date	219	410	568	770	δp		Date	219	410	568	770	δp
JAN	1955 10						SEPT	1958 11					
NOV	15		X				JUNE	16					
APR	1956 12		X		X			1959 6					
	15						L.A.=60%	11					
L.A.= 50%	1957 12							1960 11		X		X	
	19							16					
	1958 12	X	X	X	X			1961 11		X		X	
	15	X	X	X	X			16					
	1959 12							1962 11		X		X	X
	15	X	X	X	X	X		16		X		X	X
MAY	1958 11						FEB	1955 2					
OCT	16						MAR	5		X	X	X	X
	1959 11						DEC	11	X	X	X	X	
L.A.= 80%	16							17	X	X	X	X	
	1960 11	X	X				L.A.=33%	23					
	16							26					
	1961 11	X	X	X	X			1956 2					
	16							5	X	X	X	X	
	1962 11							11	X	X	X	X	X
	16							14					
JULY	1958 11							17					
	16							23					
L.A.= 50%	1959 11							1957 2					
	16		X		X	X		5					
	1960 11							11					
	16		X		X			17		X		X	
	1961 11							20		X		X	
	16		X					26	X	X	X	X	
	1962 11		X		X			1958 1	X	X		X	
	16		X		X			5		X		X	
AUG	1958 11							11		X		X	
	16		X					17	X	X	X	X	X
L.A.= 80%	1959 11							20		X		X	
	16							26	X	X	X	X	
	1960 11		X		X	X		1959 2		X		X	
	16							5	X	X		X	
	1961 11							11		X			
	16							17		X		X	
	1962 11							20	X	X	X	X	X
	16							25	X	X	X	X	

X: Exceeds Allowable

TABLE 2-2. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 100 AND Vg = 30 FT/SEC

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
FEB	1955 11	X	X	X	X	
MAR	17	X	X	X	X	
DEC	1956 11	X	X	X	X	X
	17					
L.A.= 10%	1957 11		X			
	17		X		X	
	1958 11	X	X			
	17	X	X	X	X	X
	1959 11		X			
	17		X	X	X	
MAY	1958 11					
OCT	16					
	1959 11					
L.A.=70%	16					
	1960 11		X		X	
	16					
	1961 11		X			
	16					
	1962 11		X			
	16					
JULY	1958 11					
	16					
L.A.=90%	1959 11					
	16					
	1960 11					
	16					
	1961 11					
	16					
	1962 11					
	16		X			
AUG	1958 11					
	16					
L.A.= 90%	1959 11					
	16					
	1960 11		X			
	16					
	1961 11					
	16					
	1962 11					
	16					

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
SEPT	1958 11					
JUNE	16					
	1959 11					
L.A.=60%	21					
	1960 11		X		X	
	16					
	1961 11		X		X	
	16					
	1962 11		X		X	X
	16		X		X	
JAN	1955 3					
NOV	6		X			
APR	10		X			
	15					
L.A.= 46.7%	21	X	X	X	X	
	27	X	X	X	X	X
	1956 3					
	6					
	12		X		X	
	15					
	21		X		X	
	27				X	
	1957 3					
	6	X	X	X	X	X
	12					
	19					
	21					
	27					
	1958 3	X	X	X	X	X
	6	X	X	X	X	X
	12	X	X	X	X	
	15	X	X	X	X	
	21	X	X	X	X	X
	27	X	X	X	X	X
	1959 3					
	6		X		X	
	12					
	15	X	X	X	X	X
	21					
	27					

X: Exceeds Allowable

TABLE 2-3. "X" CHART OF AC-7 TO AC-15 % LAUNCH AVAILABILITY USING PITCH PROGRAM 30 AND Vg = 30 FT/SEC

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
JAN	1955 10		X		X	
NOV	15		X		X	
APR	1956 12	X	X	X	X	X
	15					
L.A. = 30%	1957 12					
	19		X		X	
	1958 12	X	X	X	X	X
	15	X	X	X	X	X
	1959 12					
	15	X	X	X	X	X
FEB	1955 11	X	X	X	X	
MAR	17	X	X	X	X	
DEC	1956 14		X		X	
	17					
L.A. = 10%	1957 14		X	X	X	
	17		X		X	
	1958 11	X	X		X	
	17	X	X	X	X	X
	1959 14		X			
	17	X	X	X	X	
MAY	1958 11					
OCT	16					
	1959 11					
L.A. = 50%	16		X		X	
	1960 11	X	X	X	X	
	16					
	1961 11		X			
	16					
	1962 11		X		X	
	16		X		X	
JULY	1958 11					
	16					
L.A. = 100%	1959 11					
	16					
	1960 11					
	16					
	1961 11					
	16					
	1962 11					
	16					

	Date	Bending Moment At Station 219	410	568	770	Eng. Def. δp
AUG	1958 11					
	16					
L.A. = 100%	1959 11					
	16					
	1960 11					
	16					
	1961 11					
	16					
	1962 11					
	16					
SEPT	1958 1					
JUNE	6					
	11					
L.A. = 90%	16					
	21					
	26					
	1959 1					
	6					
	11					
	16					
	21					
	26					
	1960 1					
	6					
	11					
	16					
	21		X	X	X	
	26					
	1961 1					
	6		X		X	
	11	X	X	X	X	
	16					
	21					
	26					
	1962 1					
	6					
	11					
	16					
	21					
	26					

X: Exceeds Allowable

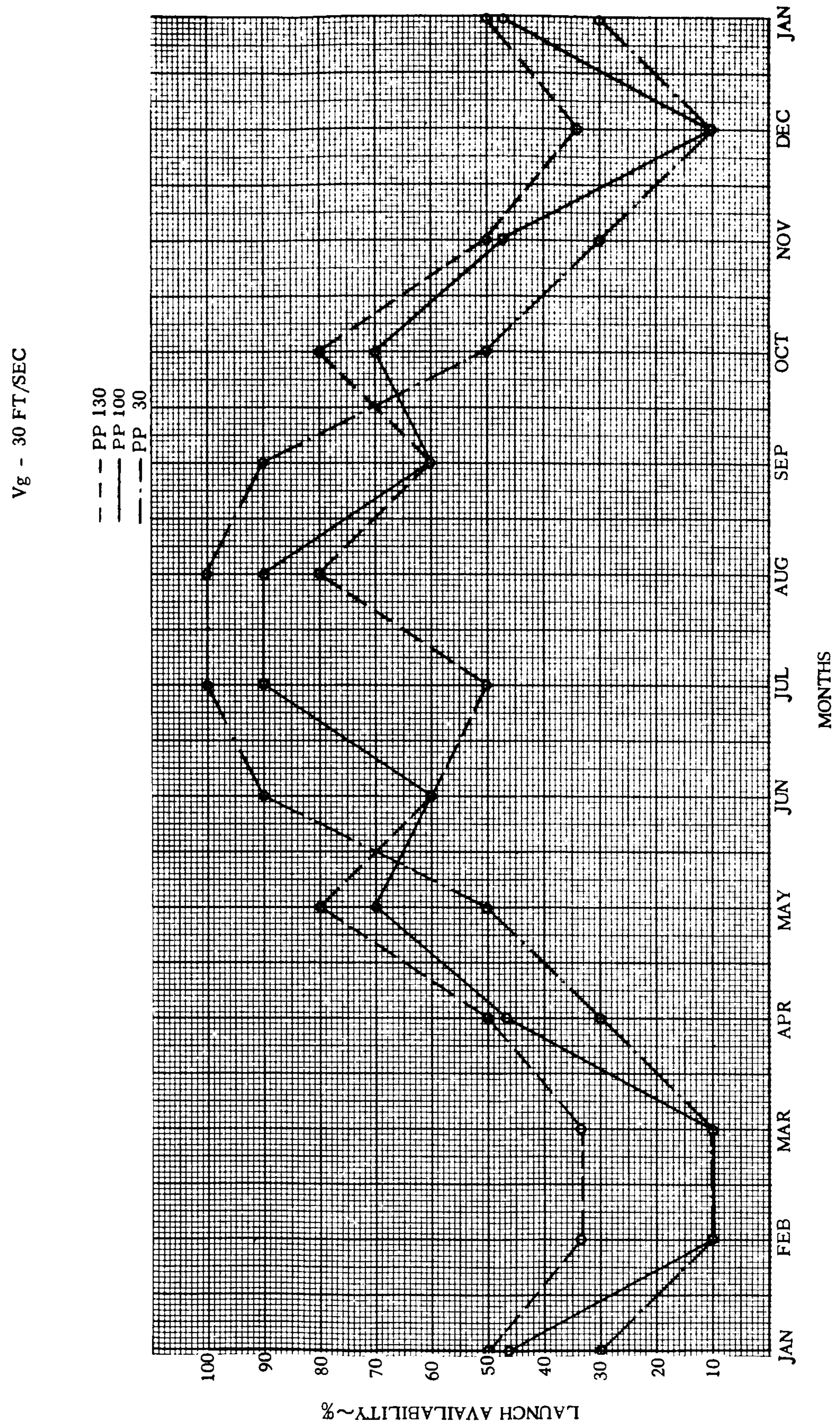


Figure 2-3. Launch Availability Versus Months Using a 30 ft/sec Gust Criterion

2W19ST

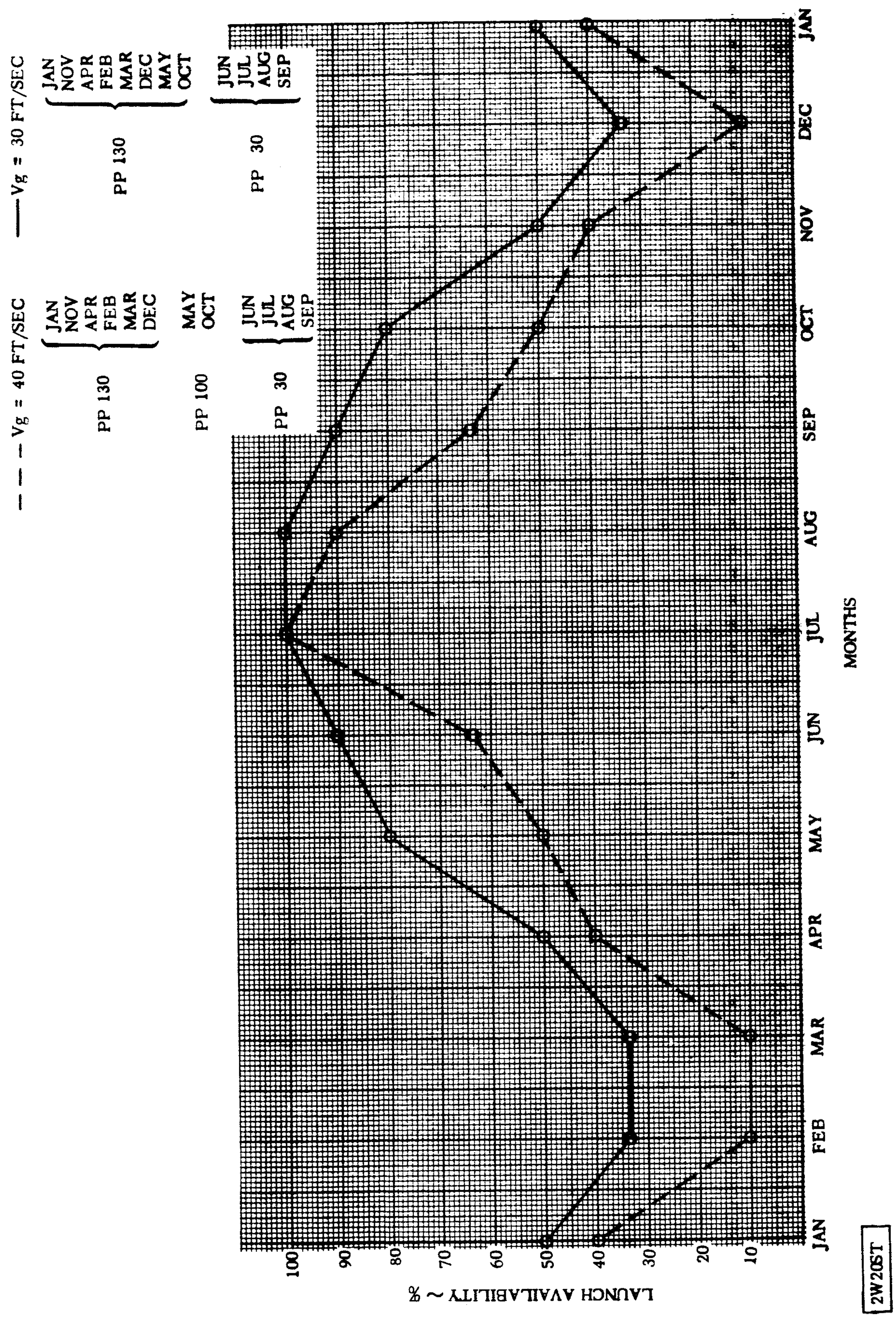


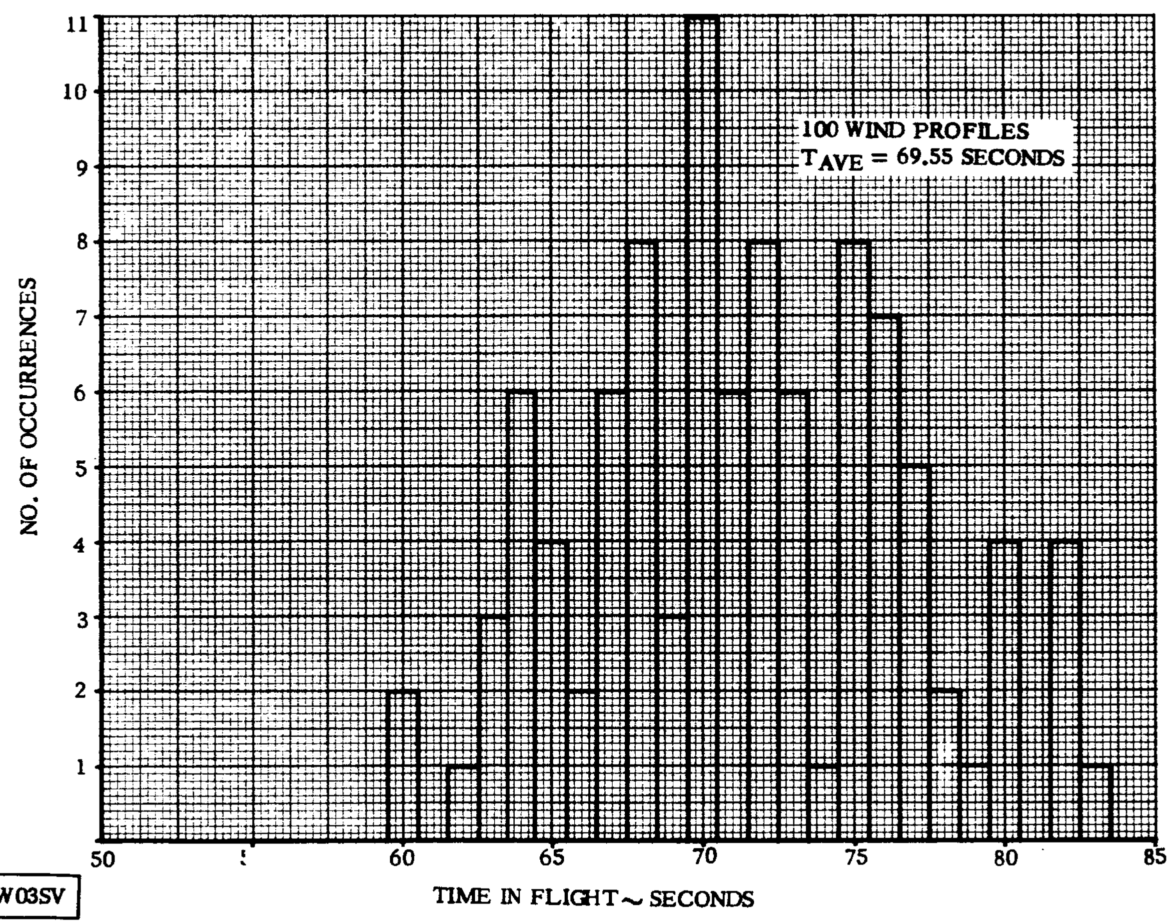
Figure 2-4. Comparison of Launch Availability for 30 ft/sec and 40 ft/sec Gust Criterion

SECTION III

PRESENT PITCH PROGRAMS

3.1 INFORMATION FROM EXISTING PITCH PROGRAMS

3.1.1 TIME IN FLIGHT FOR MAXIMUM BENDING MOMENTS. It was desired to find the time after liftoff when the maximum aerodynamic loading occurred. Referring to Figures A-1 and A-2 in the Appendix it may be noted that the maximum bending moment occurs at 64 seconds for Stations 410 and 770. By checking Atlas/Centaur (AC-7) Pitch Program Investigation Plots for 100 wind profiles Figures 3-1 and 3-2 were obtained. From Figure 3-1 for Station 410 the average time inflight for maximum bending moment was 69.55 seconds and 74 percent of the maximum bending moments occurred between 65 and 75 seconds. From Figure 3-2 for Station 770 the average time inflight for maximum bending moment was 71.48 seconds and 63 percent of the maximum bending moments occurred in between 65 and 75 seconds. From the preceding information it was decided to analyze the following increment of time Δt = 65 to 75 seconds.



2W03SV

Figure 3-1. Histograph of Time In Flight for Maximum Bending Moment at Station 410

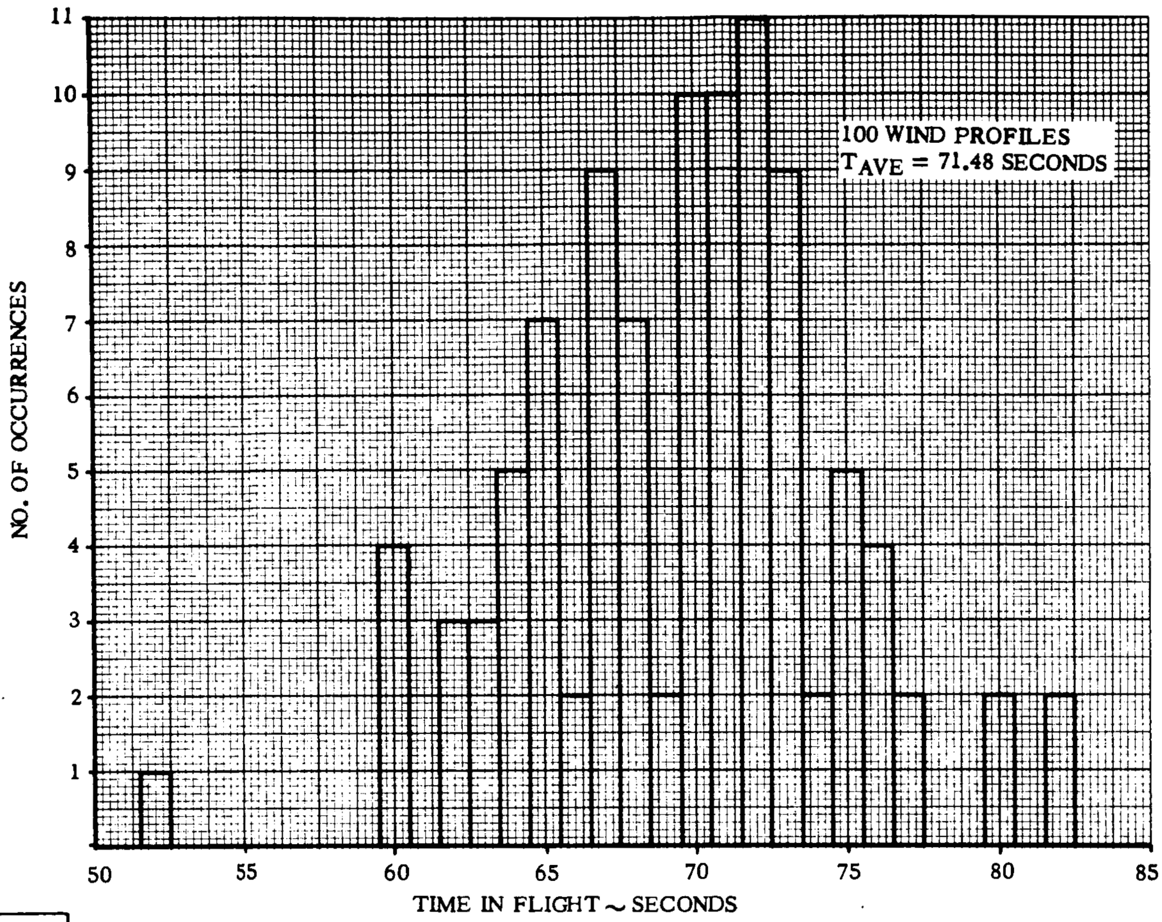


Figure 3-2. Histograph of Time In Flight for Maximum Bending Moment at Station 770

3.1.2 BAND WIDTH FOR αq and βq. Pitch Program 30 which was designed for September and June will be used in this section for sample calculations and plots. Referring to Figures A-3, A-4 in the Appendix, the plots of αq and βq versus time in flight are shown for one particular September wind. The band widths are shown for 65 to 75 seconds inflight. The band width is defined as twice the maximum value (or referred to as plus and minus the maximum value) of the variable (αq or βq) between 65 and 75 seconds. Figures 3-3 and 3-4 are Histographs for αq and βq band widths, and were obtained by using 30 wind profiles. The plots of % Launch Availability versus Band Width shown in Figures 3-5 and 3-6 were obtained from Figures 3-3 and 3-4 by the following method: If the % Launch Availability is desired for a particular band width value then % L.A. $= \frac{\Sigma N_i \times 100}{N_{TOTAL}}$ where ΣN_i is the sum of occurrences up to and including the desired band width and N_{TOTAL} is sum of all the occurrences.

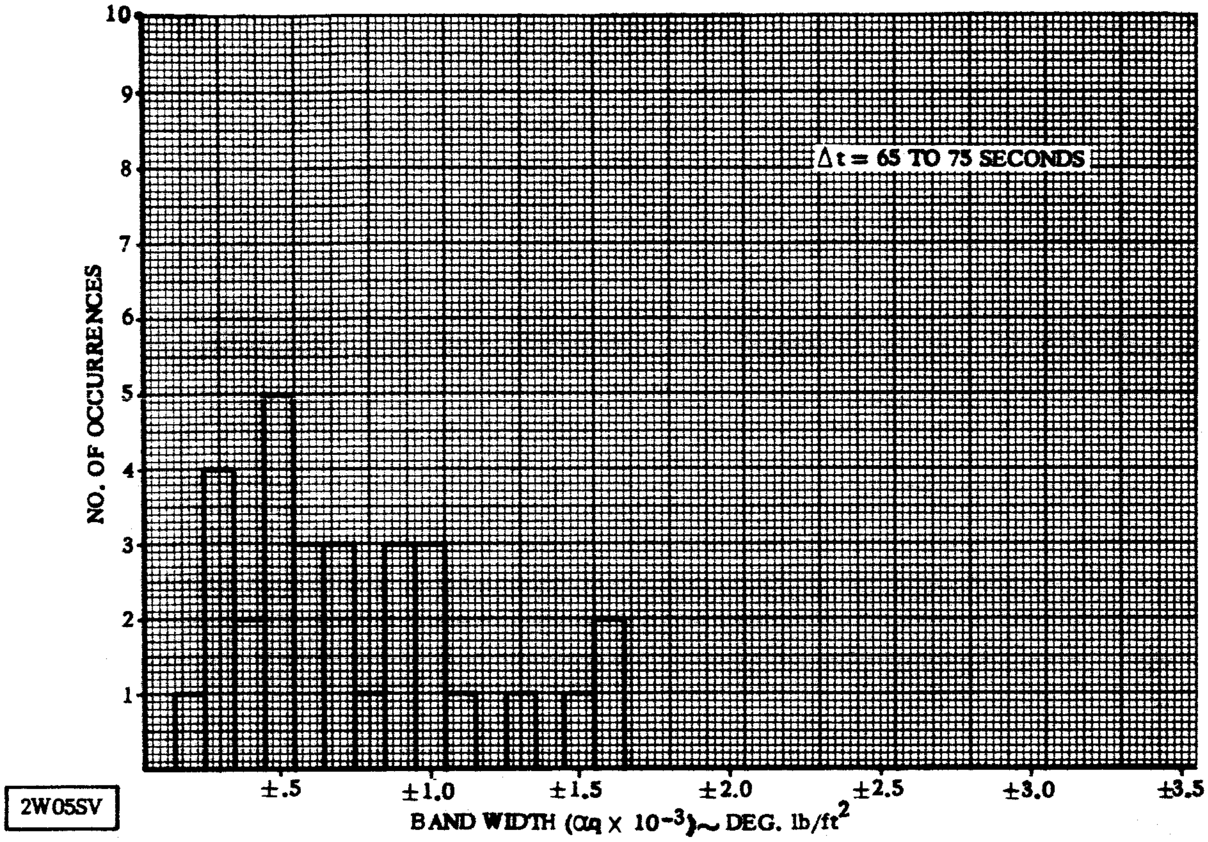


Figure 3-3. Histograph of αq for PP30 September and June

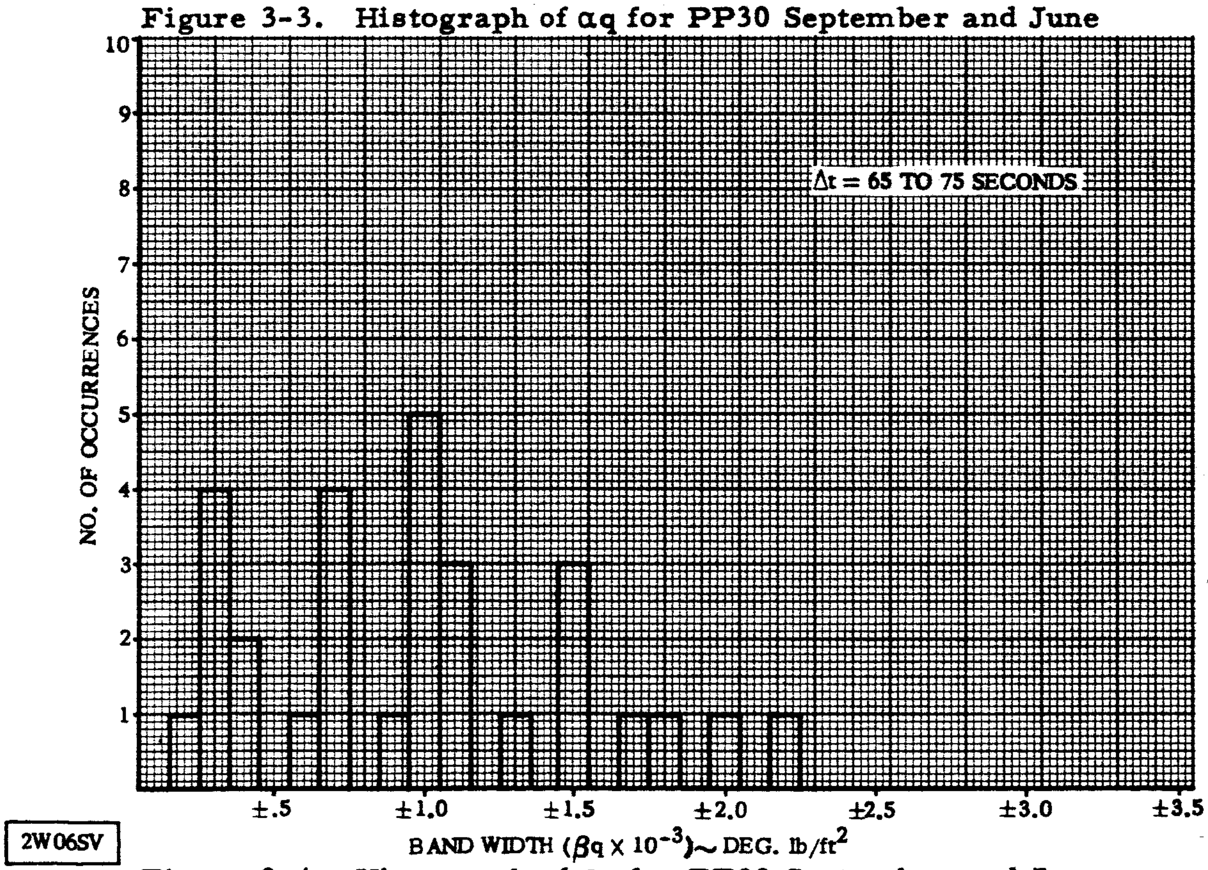
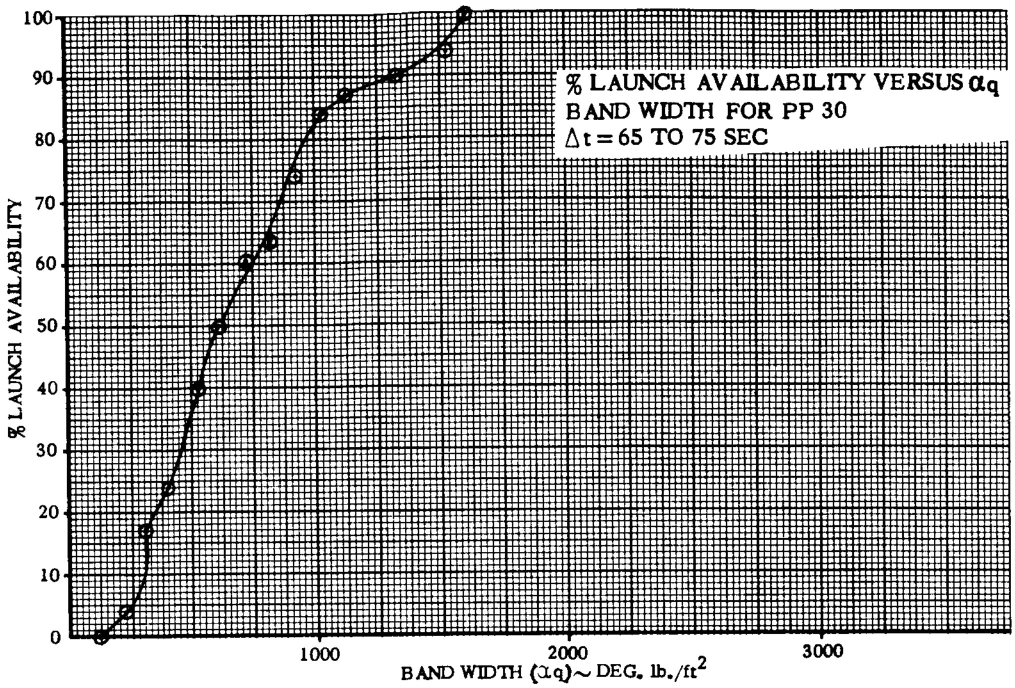
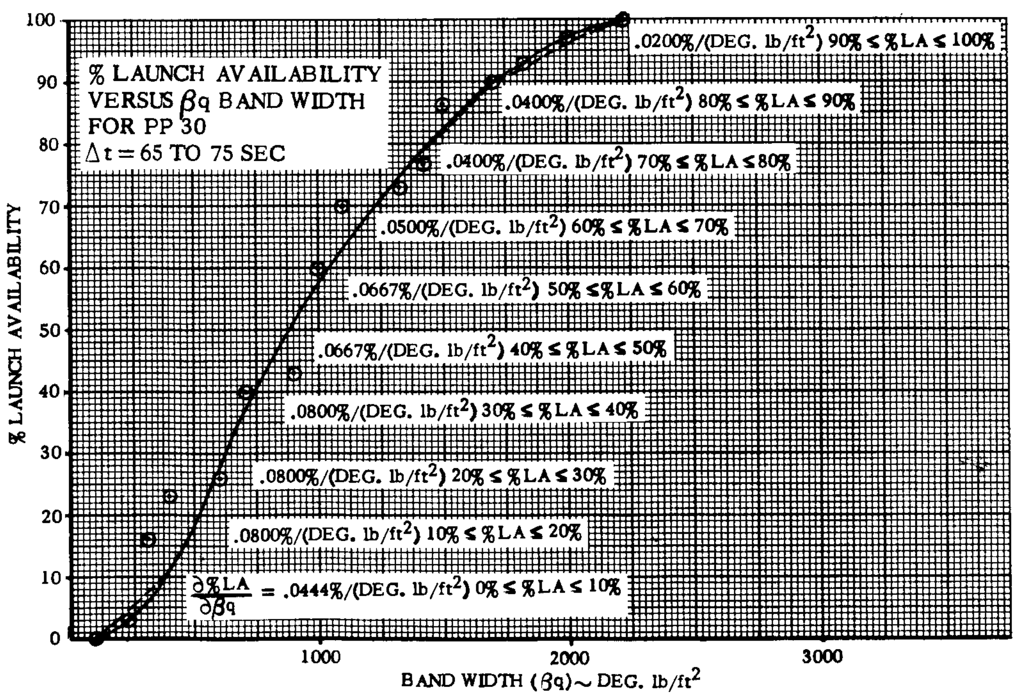


Figure 3-4. Histograph of βq for PP30 September and June



2W07SV

Figure 3-5. % Launch Availability Versus αq Band Width for PP30



2W08SV

Figure 3-6. % Launch Availability Versus βq Band Width for PP30

Now observing Figures 3-5 and 3-6 it may be noted that the βq band width is critical since the % Launch Availability is lower for a particular βq band width than it is for the same αq band width. The % Launch Availability versus βq band width curve was then approximated by several straight lines and the slopes of these lines were then calculated as shown in Figures 3-6. These slopes are actually the quantity $\frac{\partial \% LA}{\partial \beta q}$ and they are summarized in Tables 3-1 to 3-6.

3.1.3 BENDING MOMENTS NEEDED FOR SPECIFIC % LAUNCH AVAILABILITY. From Reference 4 at 68 seconds inflight the bending moment at Station 410 is 1.0383×10^6 in.-lbs., the bending moment at Station 770 is 1.3529×10^6 in.-lbs., and $\beta q = 762.44$ deg. lbs/ft^2. AC-5 was used since its configuration is very similar to AC-7 thru AC-15. Using the preceding values then the:

$$\frac{\partial BM_{410}}{\partial \beta q} = \frac{1.0383 \times 10^6 \text{ in.-lbs.}}{762.44 \text{ deg. lb/ft}^2} = 1.3618 \times 10^3 \frac{\text{in.-lbs.}}{\text{deg. lb/ft}^2} \text{ and the}$$

$$\frac{\partial BM_{770}}{\partial \beta q} = \frac{1.3529 \times 10^6 \text{ in.-lbs.}}{762.44 \text{ deg. lb/ft}^2} = 1.7744 \times 10^3 \frac{\text{in.-lbs.}}{\text{deg. lb/ft}^2}$$

Next the quantities $\frac{\partial BM}{\partial \% LA} = \frac{\left(\frac{\partial BM}{\partial \beta q}\right)}{\left(\frac{\partial \% LA}{\partial \beta q}\right)}$ were calculated for Station 410 and 770 and they are summarized in Tables 3-1 to 3-6.

TABLE 3-1. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP130) (FEB, MAR & DEC) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.0333	.0409	.0533
10-20	.0333	.0409	.0533
20-30	.0400	.0340	.0443
30-40	.2000	.0068	.0089
40-50	.0500	.0272	.0357
50-60	.0500	.0272	.0357
60-70	.0250	.0545	.0710
70-80	.1333	.0102	.0133
80-90	.0444	.0307	.0400
90-100	.0067	.2033	.2648

TABLE 3-2. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP100) (JAN, NOV & APR) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.0200	.0680	.0890
10-20	.0500	.0272	.0357
20-30	.1000	.0136	.0177
30-40	.0400	.0340	.0443
40-50	.0667	.0203	.0265
50-60	.1333	.0102	.0133
60-70	.0769	.0177	.0231
70-80	.0308	.0442	.0576
80-90	.0211	.0645	.0840
90-100	.0067	.2033	.2648

TABLE 3-3. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP70) (MAY & OCT) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.0800	.0170	.0222
10-20	.0800	.0170	.0222
20-30	.1333	.0102	.0133
30-40	.1000	.0136	.0177
40-50	.0800	.0170	.0222
50-60	.0800	.0170	.0222
60-70	.0571	.0238	.0310
70-80	.0571	.0238	.0310
80-90	.0333	.0409	.0533
90-100	.0082	.1661	.2164

TABLE 3-4. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP30) (SEPT & JUNE) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.0444	.0307	.0400
10-20	.0800	.0170	.0222
20-30	.0800	.0170	.0222
30-40	.0800	.0170	.0222
40-50	.0667	.0204	.0266
50-60	.0667	.0204	.0266
60-70	.0500	.0272	.0357
70-80	.0400	.0340	.0443
80-90	.0400	.0340	.0443
90-100	.0200	.0680	.0890

TABLE 3-5. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP0) (AUG) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.1333	.0102	.0133
10-20	.1000	.0136	.0177
20-30	.0667	.0204	.0266
30-40	.1000	.0136	.0177
40-50	.2000	.0068	.0089
50-60	.1000	.0136	.0177
60-70	.0800	.0170	.0222
70-80	.1000	.0136	.0177
80-90	.1333	.0102	.0133
90-100	.0108	.1261	.1643

TABLE 3-6. PARTIAL DERIVATIVE OF % L.A. WITH RESPECT TO βq AND PARTIAL DERIVATIVE OF BENDING MOMENT WITH RESPECT TO % L.A. FOR (PP-20) (JULY) (65 SEC < t < 75 SEC)

% Launch Availability (%)	$\frac{\partial \% LA}{\partial \beta q}$ (%/deg. lb/ft^2)	$\frac{\partial BM_{410}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)	$\frac{\partial BM_{770}}{\partial \% LA} \times 10^{-6}$ (in.-lbs/% LA)
0-10	.0500	.0272	.0357
10-20	.0571	.0238	.0310
20-30	.0800	.0170	.0222
30-40	.1333	.0102	.0133
40-50	.1333	.0102	.0133
50-60	.0800	.0170	.0222
60-70	.1333	.0102	.0133
70-80	.2000	.0068	.0089
80-90	.0444	.0307	.0400
90-100	.0129	.1056	.1376

Now using PP30 for September and June the % L.A. = 63% for Vg = 40 ft/sec, from Table 1-10, and the present available bending moment at Station 770 = 5.30 x 10^6 in.-lbs. Using the above information and Table 3-4 the following calculation will show how much bending moment is needed for % L.A.= 100% at Station 770 in September and June:

$$BM_{\%LA=100\%} = BM_{\%LA=63\%} + \left.\frac{\partial BM}{\partial \% LA}\right|_{60\% \le \% LA \le 70} (70\% - 63\%) + \left.\frac{\partial BM}{\partial \% LA}\right|_{70\% \le \% LA \le 80} (80\% - 70\%)$$

$$+ \left.\frac{\partial BM}{\partial \% LA}\right|_{80\% \le \% LA \le 90\%} (90\% - 80\%) + \left.\frac{\partial BM}{\partial \% LA}\right|_{90\% \le \% LA \le 100\%} (100\% - 90\%)$$

$$BM_{\%LA=100\%} = 5.3 \times 10^6 \text{ in.-lbs.} + (.0357 \times 10^6)(7) \text{in.-lbs.} + (.0443 \times 10^6)(10) \text{in.-lbs.}$$
$$+ (.0443 \times 10^6)(10) \text{ in.-lbs.} + (.0890 \times 10^6)(10) \text{ in.-lbs.}$$

$$BM_{\%LA=100\%} = 7.32 \times 10^6 \text{ in.-lbs.}$$

Using similar calculations for all six pitch programs so that 30 samples would be available for each month, the bending moments needed for specific percent launch availabilities for Stations 410 and 770 using gust velocities of 40 ft/sec. and 30 ft/sec. are shown in Figures 3-7 to 3-10. It should be noted that launch availabilities quoted in this section are less than optimum since the pitch programs listed on page 1-2 were used.

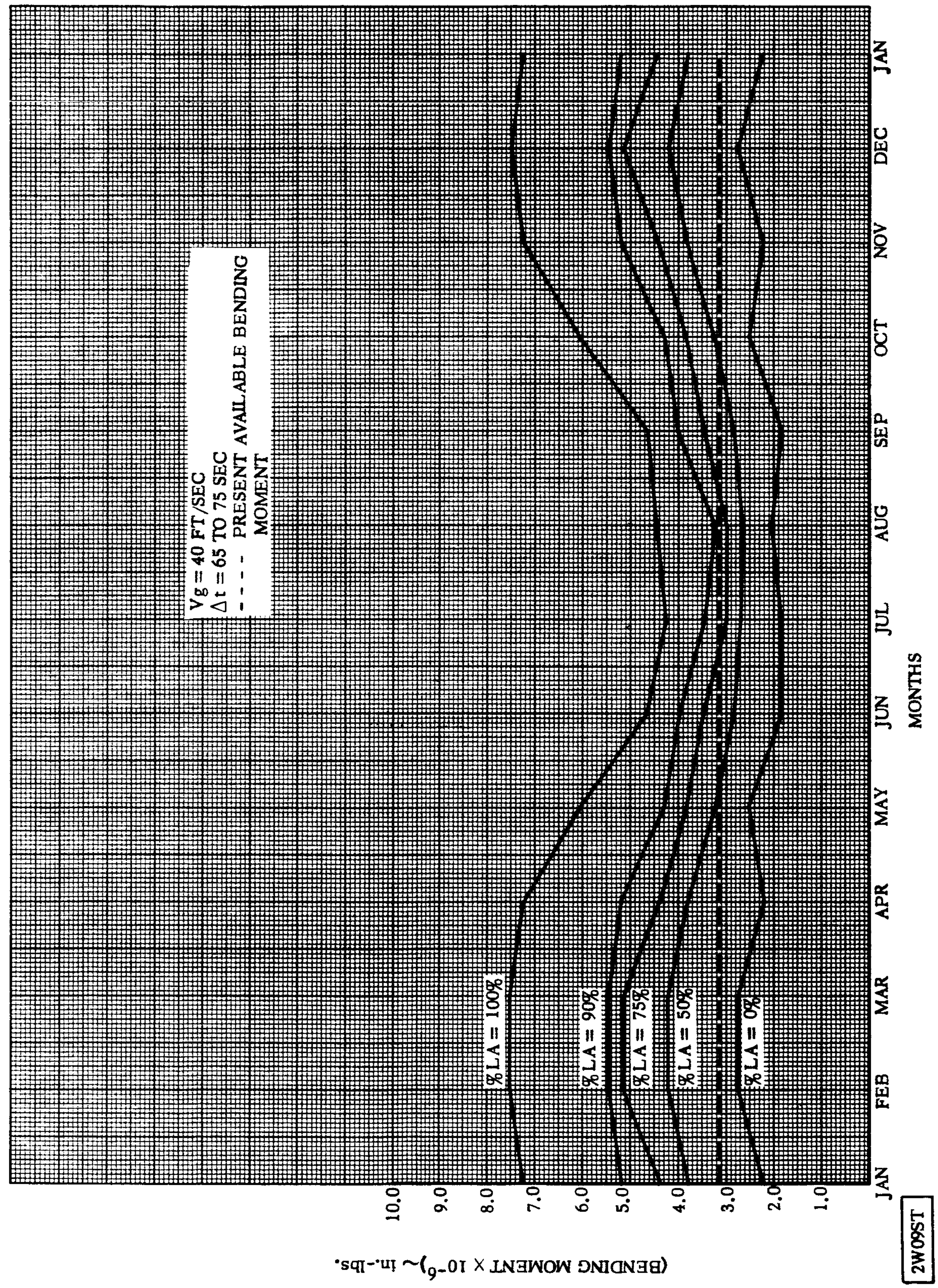


Figure 3-7. Bending Moments Needed for Specific Launch Availability Versus Months for Station 410 (40 ft/sec)

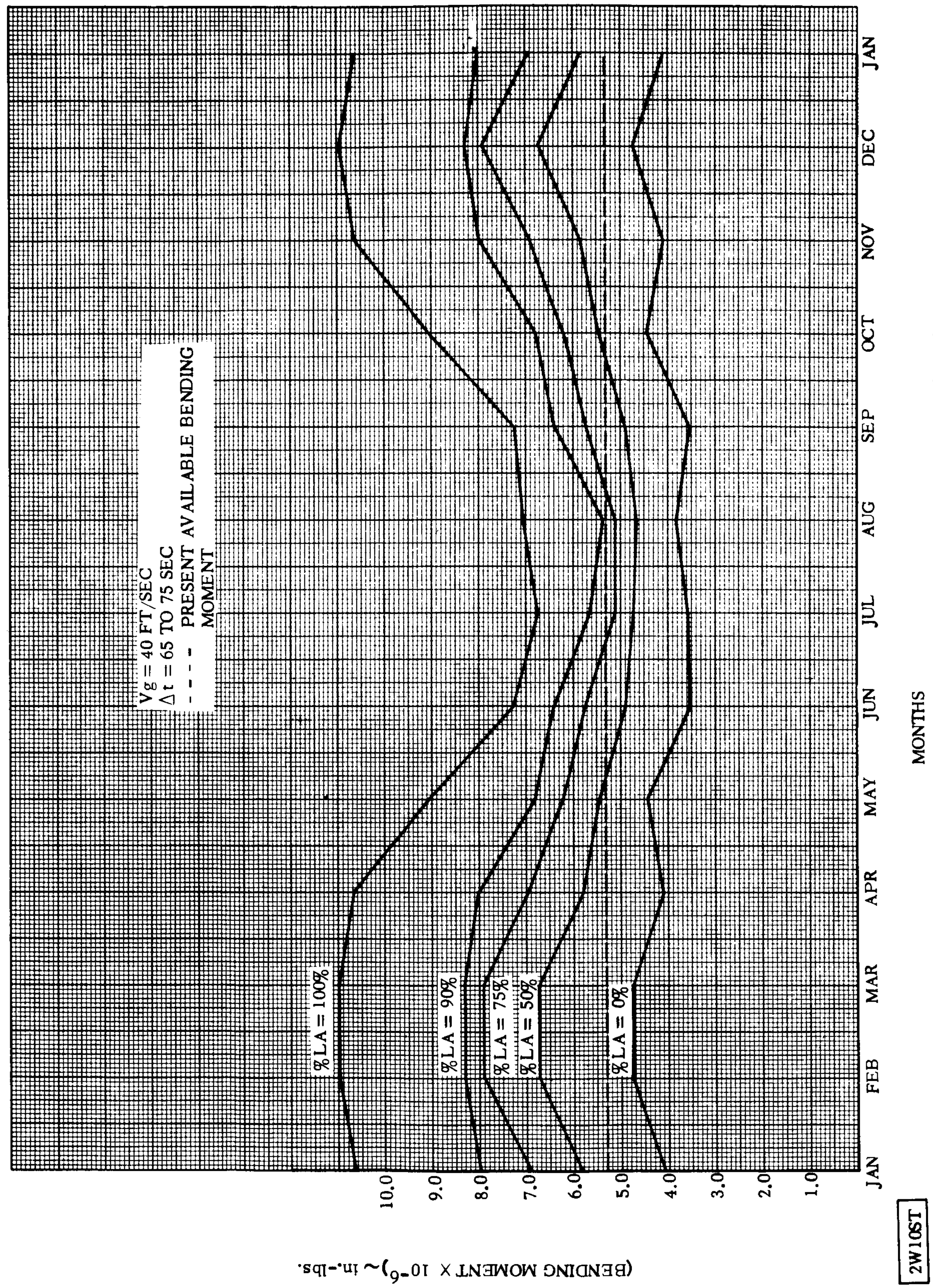


Figure 3-8. Bending Moments Needed for Specific Launch Availability Versus Months for Station 770 (40 ft/sec)

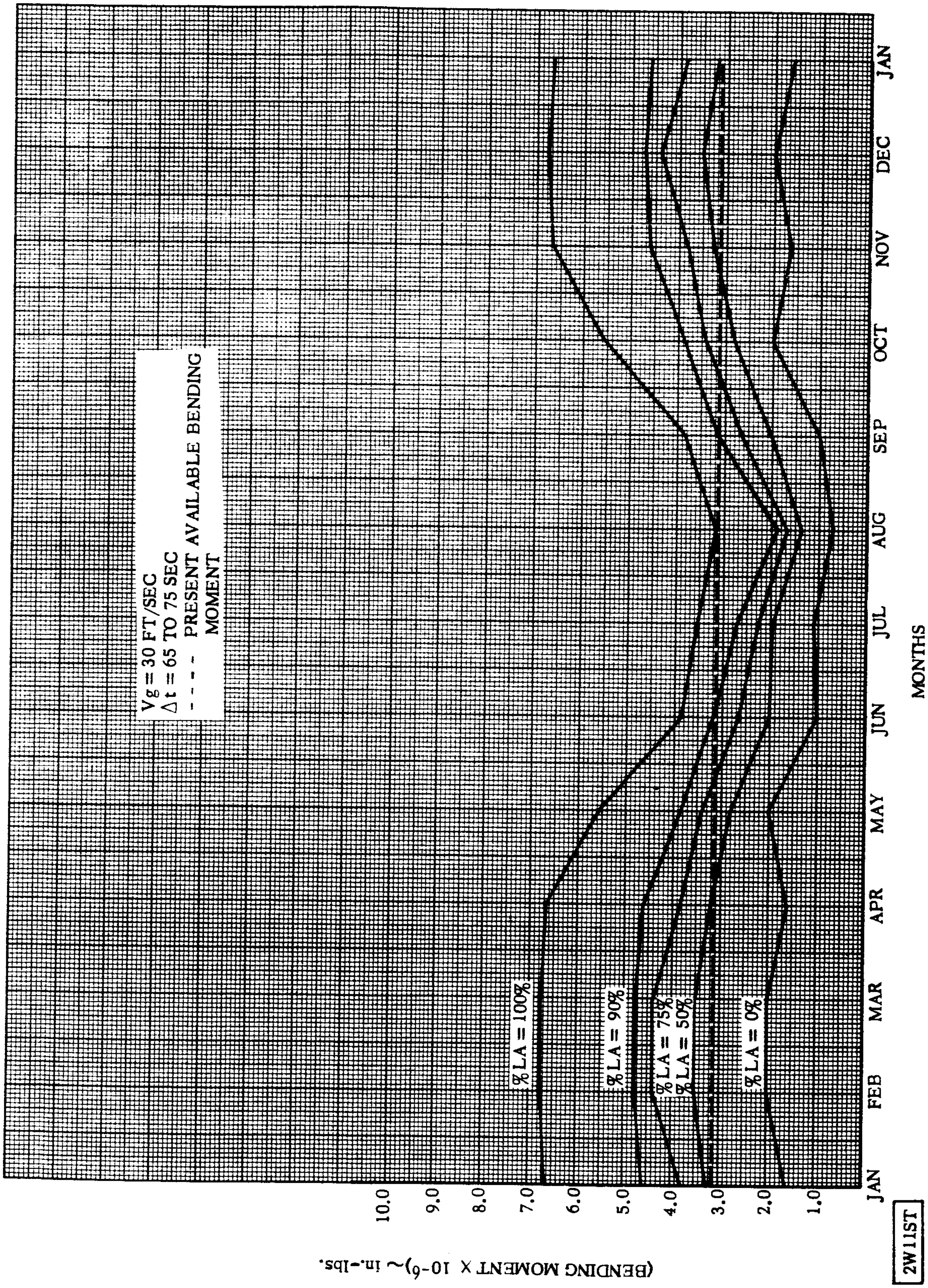
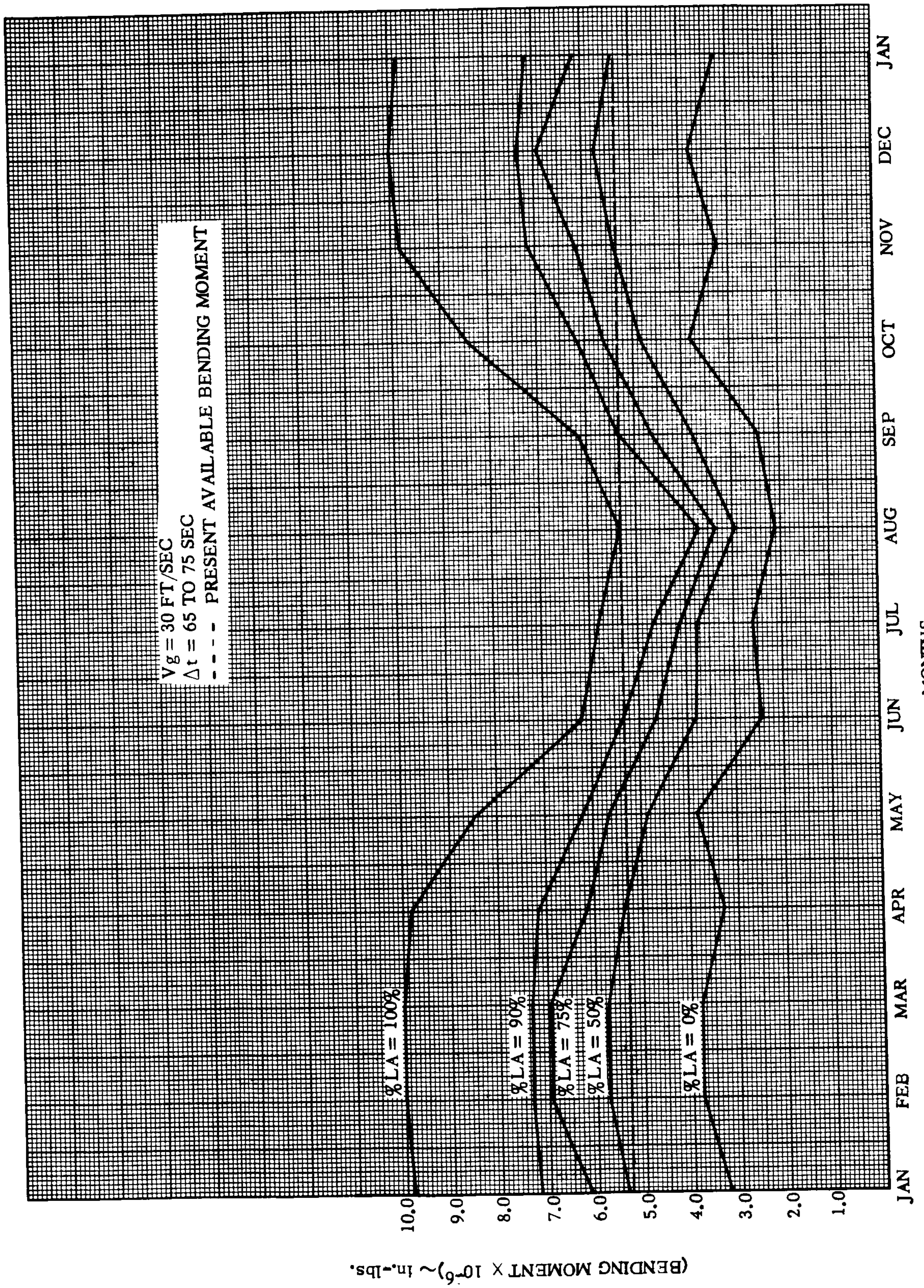


Figure 3-9. Bending Moments Needed for Specific Launch Availability Versus Months for Station 410 (30 ft/sec)



2W12ST

Figure 3-10. Bending Moments Needed for Specific Launch Availability Versus Months for Station 770 (30 ft/sec)

When βq is large the bending moment needed for a particular percent launch availability in the range of $90\% \leq \%$ L.A. $\leq 100\%$ is also large. Since the sample size was 30 which is relatively small the maximum βq's found are not as large as they would be with a large sample, therefore, the bending moments needed for % L.A. = 100% are probably larger than the values found in Figures 3-7 to 3-10. It is felt that the bending moments needed for $0\% \leq$ % L.A. $\leq 90\%$ in Figures 3-7 to 3-10 are accurate under the assumptions that were made in the analysis.

3.2 INFORMATION FOR IMPROVED PITCH PROGRAMS AND NEW YAW PROGRAMS

An ideal pitch program generates an approximately zero angle-of-attack at any time inflight. By observing the SC 4020 plots, Atlas/Centaur (AC-7) Pitch Program Investigation, it was found that the angle-of-attack average for many winds at a given time was not approximately zero so it was decided that improved pitch programs and new yaw programs are needed.

3.2.1 AVERAGE INCREMENTAL ANGLE-OF-ATTACK ($\Delta\alpha$ AND $\Delta\beta$). The values of ($\Delta\alpha$) in the alpha plane and the values of ($\Delta\beta$) in the beta plane were found for 10 second increments in the range of 40 seconds $\leq t \leq 90$ seconds. Referring to Figure A-5 in the Appendix for Δt = 50 to 60 seconds or t = 55 seconds it was found that the angle-of-attack is equal to -.8 degrees, therefore, the angle-of-attack should be biased by an incremental $\Delta\alpha$ = +.8 degrees to give zero angle-of-attack in this case. After checking 30 SC 4020 plots for September wind profiles it was found that the average $\Delta\alpha$ = -.1 degrees. The current no wind bias = .3 degrees and subtracting .1 degrees from this value the best no wind bias = +.2 degrees for September. Using the same procedure as shown above for the best three pitch programs Table 3-1 to 3-3 were obtained. Figure 3-11 shows a plot of the average incremental angle-of-attack versus time inflight for the alpha and beta planes. By using these values of the average incremental angle-of-attack better pitch and new yaw programs can be generated.

3.2.2 CONCLUSIONS. The information from Figure 3-11 has been sent to the Centaur Aeroballistics Group. After they develop new pitch and yaw programs, the results will be returned to the Centaur Dynamics Group. From this point, the information will be used to obtain new Atlas/Centaur (AC-7) Pitch Program Investigation Plots. These plots will then be checked to determine how much the percent launch availability will be increased.

TABLE 3-7. CURRENT NO WIND BIAS, AVERAGE INCREMENTAL ANGLE ANGLE OF ATTACK, AND BEST NO WIND BIAS FOR PP 130

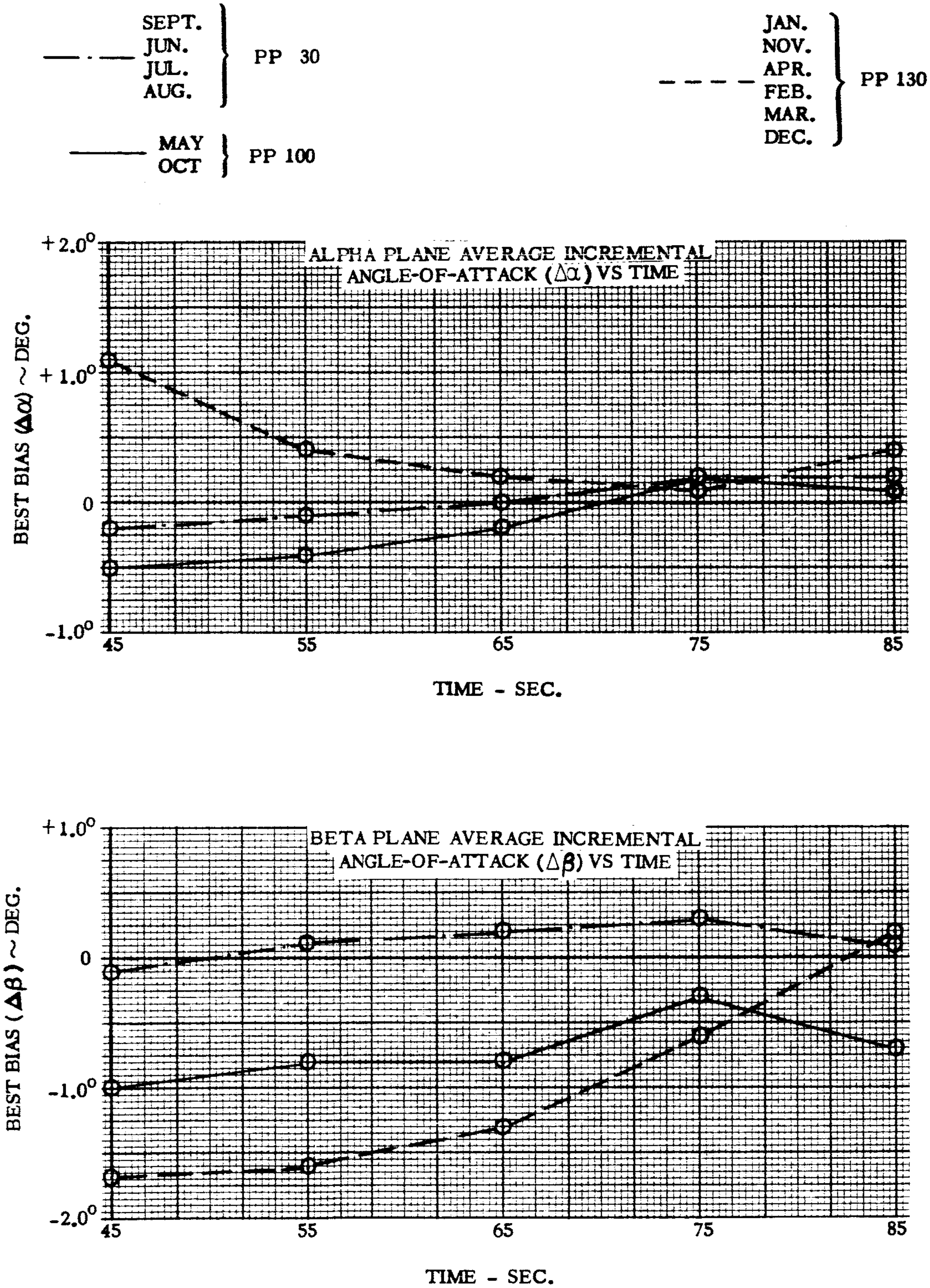
Time (sec) $\Delta\alpha$	Current No Wind Bias	Average Incremental Angle of Attack ($\Delta\alpha$)	Best No Wind Bias
45	+1.3	+1.1	+2.4
55	+1.7	+ .4	+2.1
65	+1.4	+ .2	+1.6
75	+ .6	+ .1	+ .7
85	- .5	+ .4	- .1
Time (sec) $\Delta\beta$	**Current No Wind Bias**	**Average Incremental Angle of Attack ($\Delta\beta$)**	**Best No Wind Bias**
45	0	-1.7	-1.7
55	0	-1.6	-1.6
65	0	-1.3	-1.3
75	- .1	- .6	- .7
85	- .1	+ .2	+ .1

TABLE 3-8. CURRENT NO WIND BIAS, AVERAGE INCREMENTAL ANGLE ANGLE OF ATTACK, AND BEST NO WIND BIAS FOR PP 100

Time (sec) $\Delta\alpha$	Current No Wind Bias	Average Incremental Angle of Attack ($\Delta\alpha$)	Best No Wind Bias
45	+1.3	- .5	+ .8
55	+1.2	- .4	+ .8
65	+1.0	- .2	+ .8
75	+ .3	+ .2	+ .5
85	- .7	+ .1	- .6
Time (sec) $\Delta\beta$	**Current No Wind Bias**	**Average Incremental Angle of Attack ($\Delta\beta$)**	**Best No Wind Bias**
45	0	-1.0	-1.0
55	0	- .8	- .8
65	0	- .8	- .8
75	- .1	- .3	- .4
85	- .1	- .7	- .8

TABLE 3-9. CURRENT NO WIND BIAS, AVERAGE INCREMENTAL ANGLE ANGLE OF ATTACK, AND BEST NO WIND BIAS FOR PP 30

Time (sec) $\Delta\alpha$	Current No Wind Bias	Average Incremental Angle of Attack ($\Delta\alpha$)	Best No Wind Bias
45	+ .4	- .2	+ .2
55	+ .3	- .1	+ .2
65	+ .3	0	+ .3
75	- .1	+ .2	+ .1
85	- .5	+ .2	- .3
Time (sec) $\Delta\beta$	**Current No Wind Bias**	**Average Incremental Angle of Attack ($\Delta\beta$)**	**Best No Wind Bias**
45	+ .1	- .1	0
55	0	+ .1	+ .1
65	0	+ .2	+ .2
75	- .1	+ .3	+ .2
85	- .1	+ .1	0



2W13SV

Figure 3-11. Average Incremental Angle-of-Attack ($\Delta\alpha$ and $\Delta\beta$) Versus Time

SECTION IV

REFERENCES

1. Centaur Monthly Configuration, Performance and Weight Status Report (U) Report No. GD/A63-0495-9, dated 21 February 1964. S.A. Zobal.

2. Monthly and Annual Wind Distribution as a Function of Altitude for Patrick Air Force Base, Cape Kennedy, Florida. Smith, J. W. and Vaughn, W. W. Report No. NASA TN D-610, dated July 1961.

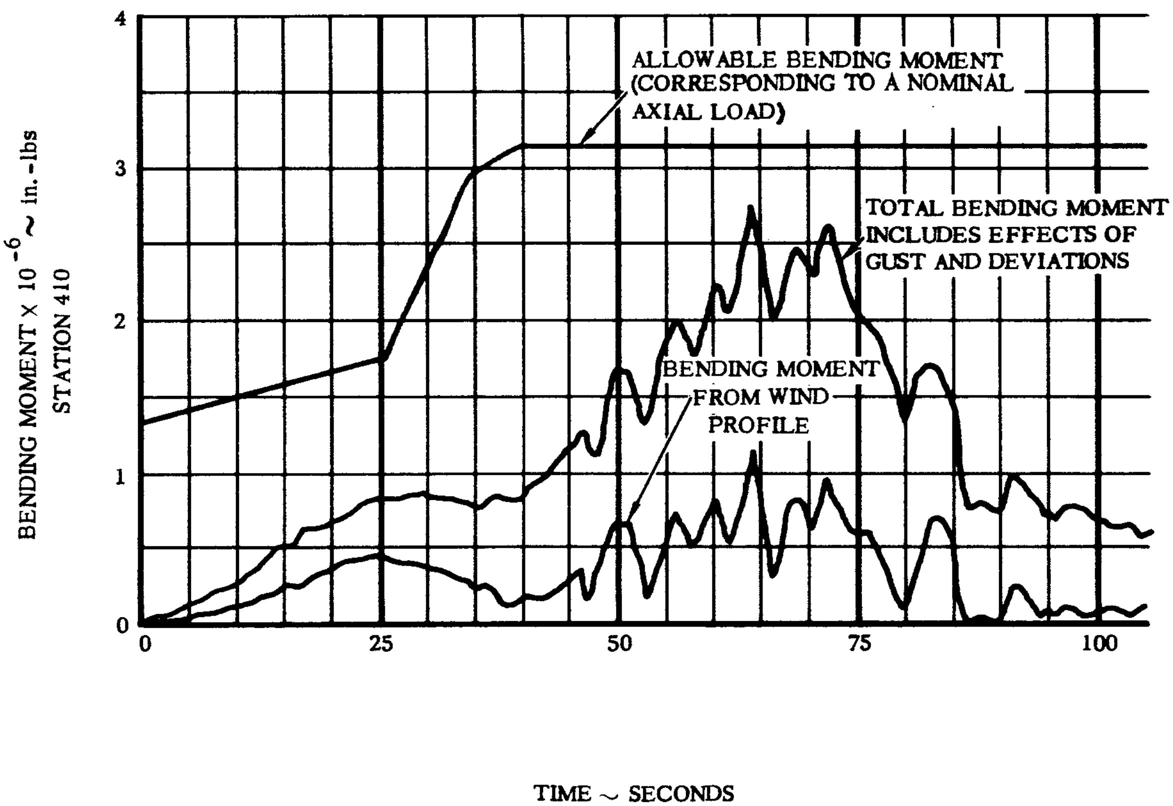
3. Flight Wind Restriction Procedure Atlas/Centaur Flight AC-3. Report No. GD/A BTD 64-070, dated 15 March 1964. J.A. Steele.

4. Atlas/Centaur, AC-5, Static Aeroelastic Factors; GD/A Memo SD-65-10-CEN, 18 January 1965. Author R. Hintz.

APPENDIX A

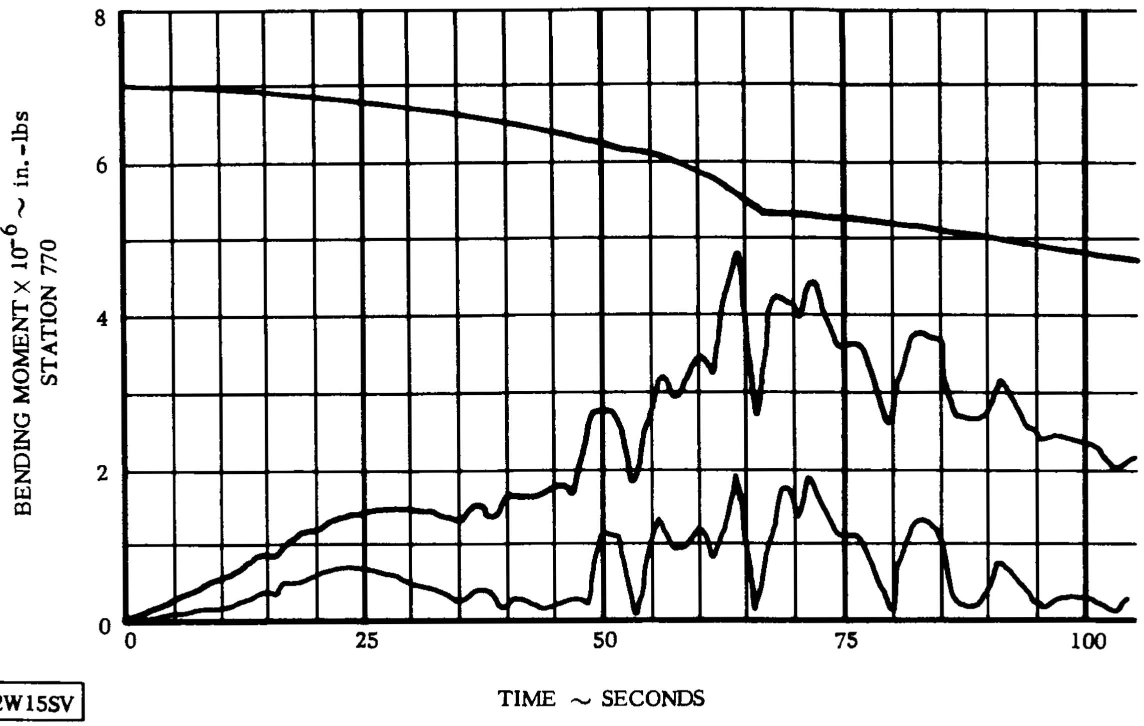
A-1.1 INTRODUCTION

A-1.1.1 SAMPLE ATLAS/CENTAUR (AC-7) PITCH PROGRAM INVESTIGATION. The following five figures, Figures A-1 through A-5, are a sample of a particular wind profile.



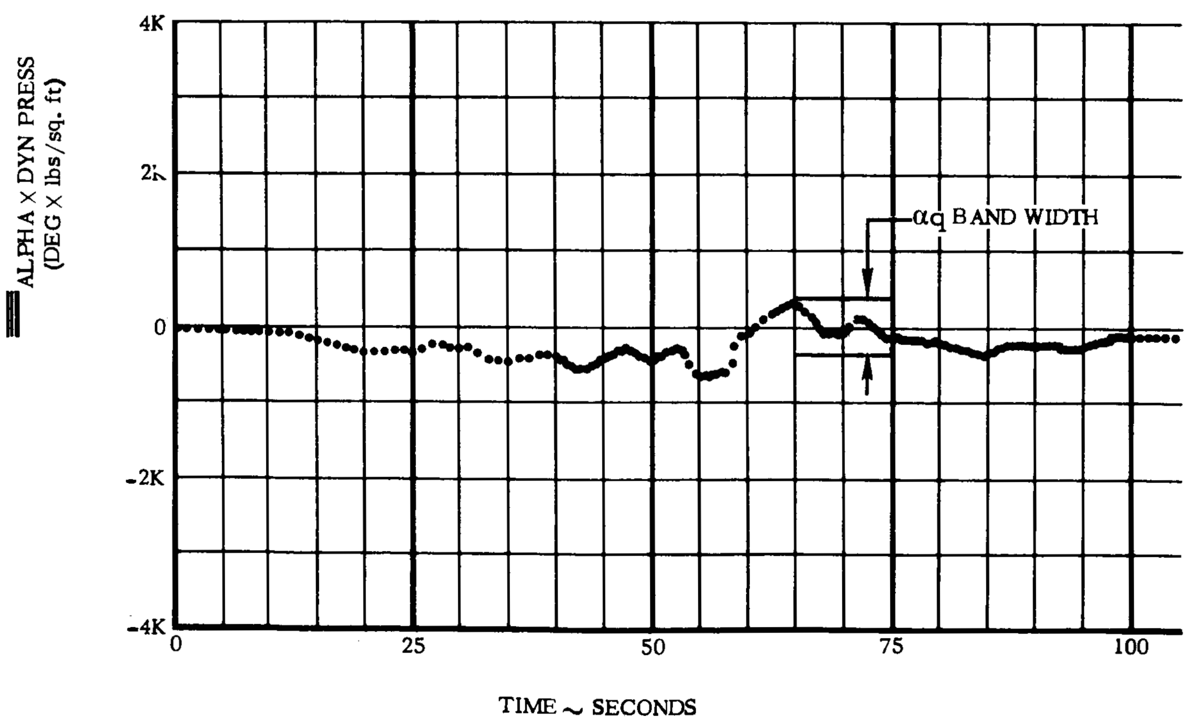
2W14SV

Figure A-1. Atlas/Centaur (AC-7) Pitch Program Investigation Bending Moment Station 410 versus Time



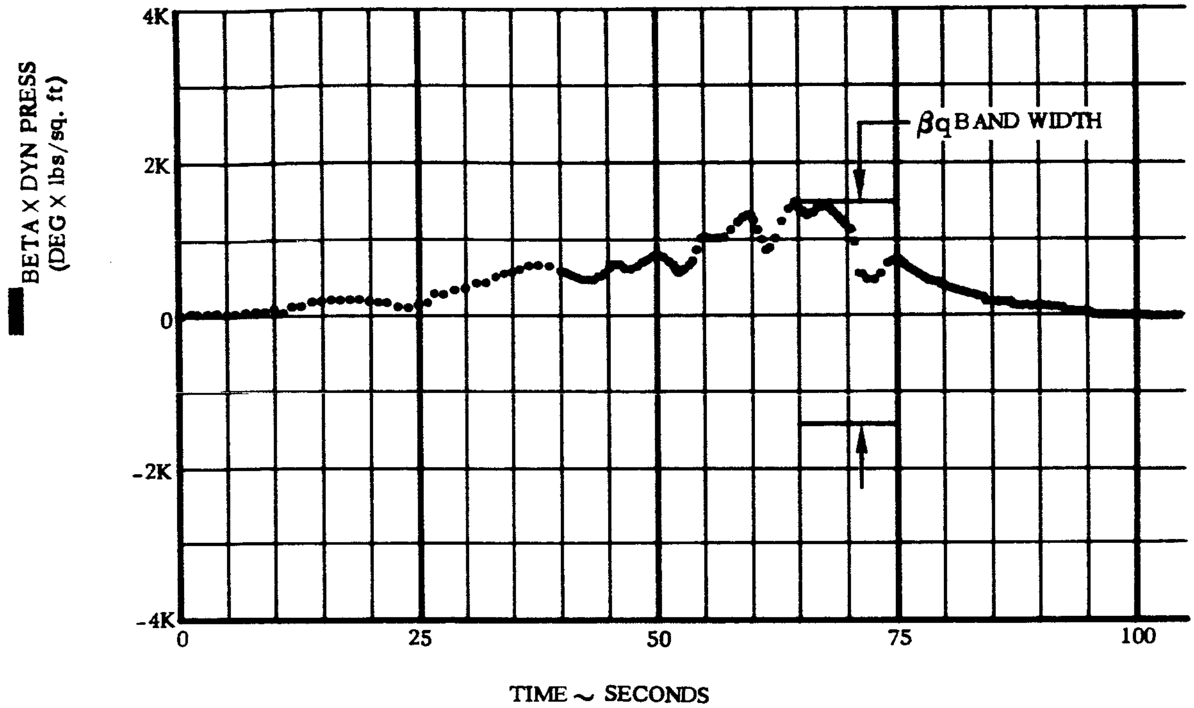
2W15SV

Figure A-2. Atlas/Centaur (AC-7) Pitch Program Investigation Bending Moment Station 770 versus Time



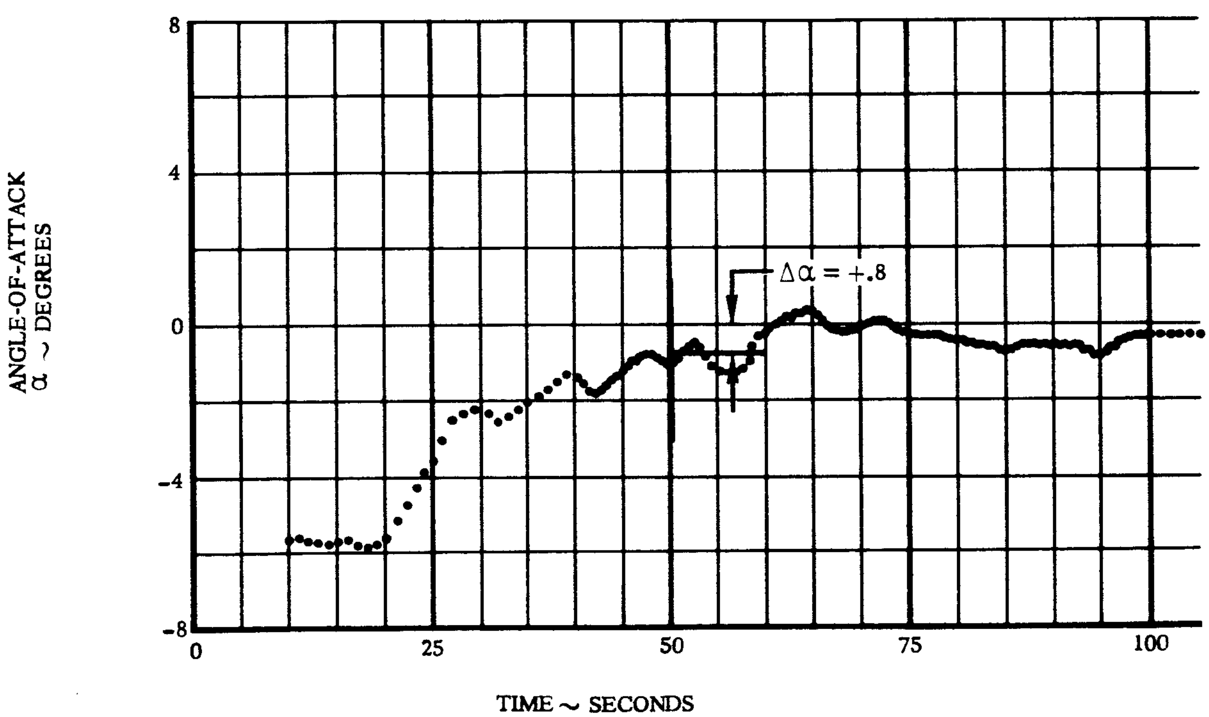
2W16SV

Figure A-3. Atlas/Centaur (AC-7) Pitch Program Investigation αq versus Time



2W17SV

Figure A-4. Atlas/Centaur (AC-7) Pitch Program Investigation
βq versus Time



2W18SV

Figure A-5. Atlas/Centaur (AC-7) Pitch Program Investigation
Alpha versus Time